Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

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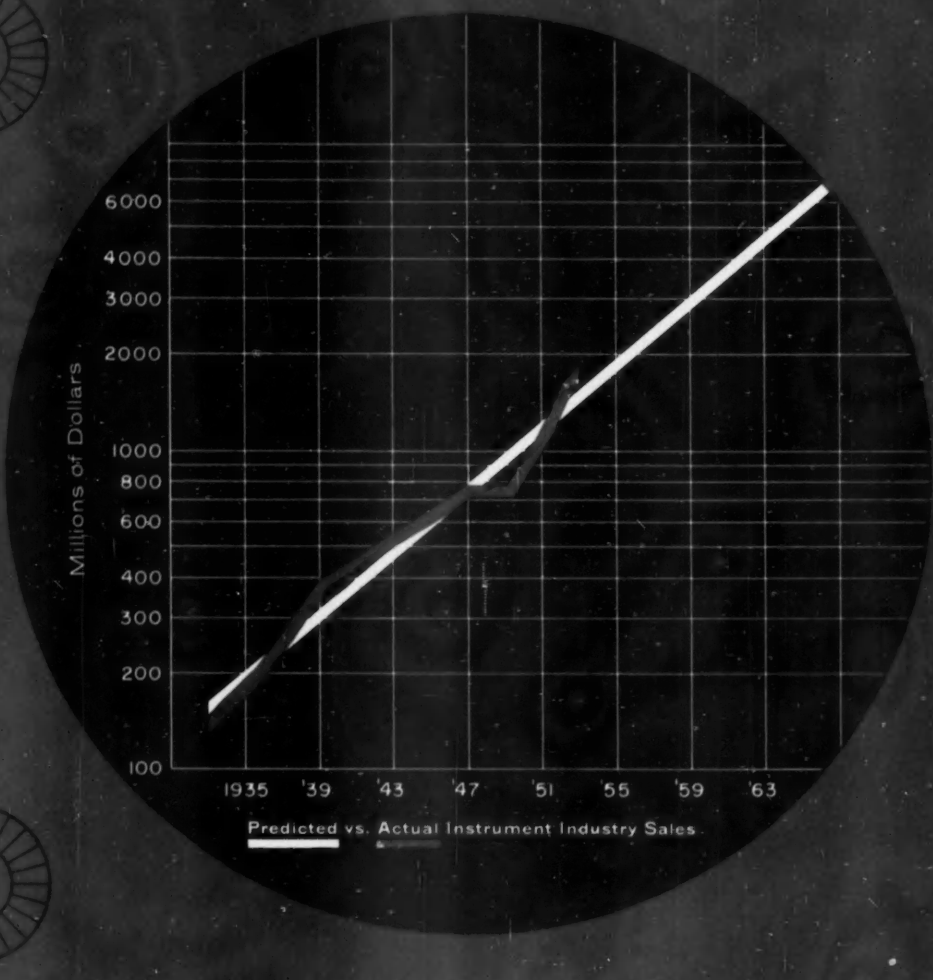
JULY 1956



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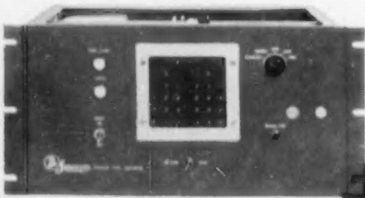

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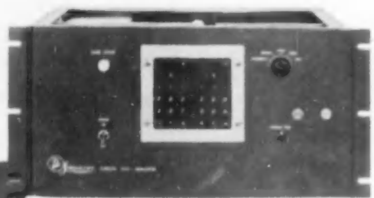

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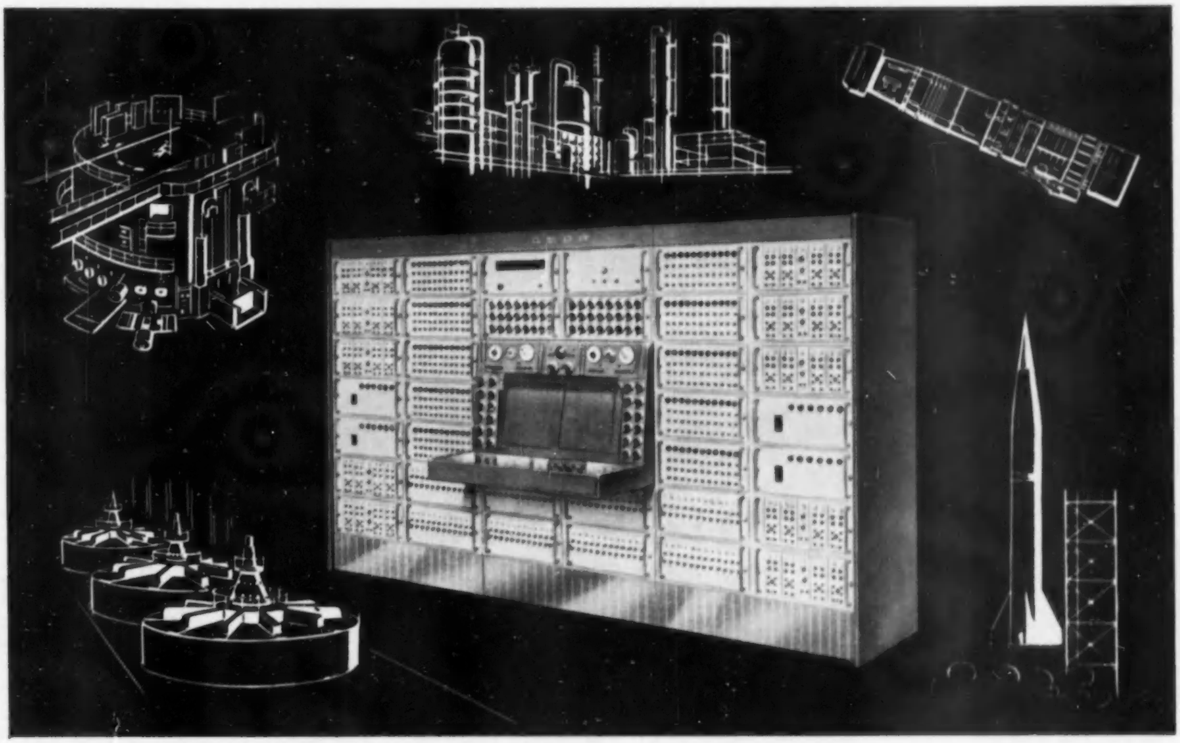

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Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

JULY 1956

FEATURE ARTICLES

IDEAS AT WORK

DEPARTMENTS

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SHOPTALK

MEASURING MEASUREMENT—WITH FEEDBACK

This month we turn a basic tool of our trade in upon itself and measure the growth of measurement. First the cover: this sets up a nice semi-log scale for our studies. Then in *What's New*, page 16, we tell how this scale was first created by theoretical techniques, then verified with actual date. Next, *Industry's Pulse*, page 61, reels off these data for those skeptics who simply will never believe a graph or an equation. And, finally, our Editorial, page 67, sends forth an unnerving feedback signal that challenges all of the foregoing and suggests, "Are we really measuring what we want to measure?" Oh, yes: go back to page 13 and meet Ralph Webb, our Control Personality, the man who placed the largest single industrial instrument order that we know of (a mere $1 million, it was). After all, what good is a growth phenomenon unless we understand its causes?—and Ralph Webb is certainly a major one.

OUR MOBILE SENSING ELEMENT

Corralling and correlating all this vaguely interconnected material was Lloyd (Slortnoc) Slater, who acted as our mobile sensing element during the past several months. First he latched on to H. C. Dickinson's report (page 17) and sequestered it until he could go to Washington and badger Census for advanced data on its 1954 assay of instrument industry sales. In the interim he whisked down to West Virginia to interview and click his Graphic merrily at Ralph and his outstanding Instrumentation Group at Carbide & Carbon. On May 25 everything meshed: Census 'phoned the last bit of data; Dickinson's theory was proved; Webb's sketch was okayed; and the "feedback" signal was created in cooperation with Bill Vannah.

"Rover" Finally Made It

Last month (page 117) we described Professor Verhagen's electronic pooch—which we had never seen. Our line sketch showed how our artist visualized him, and judging by the photo that finally came, he was pretty close. That's the Professor "feeding" his creation.

FEEDBACK

You asked for a recipe . . .

I am in the managerial end of business. Having to devise systems for data collection to satisfy data processing systems is a future problem. Your magazine contains much helpful information in regard to the physical systems but none on how managers must develop data collection systems to meet the demands of data processing systems.

May we have articles about such matters?

Henry W. Peabody
Dayton, Ohio

. . . and we bake a cake.

In our editorial bank, gathering interest, is an article by Charles Faulkner of Speigel, Inc., Chicago. Although it does not spell out how to develop data collection systems, the article does describe the steps of "cost analyses of the proposed (electronic data processing) system versus your present system". Look for it; let us know whether it serves some of your needs. Ed.

You asked for it and . . .

To the Editor—

Prompted by the article on page 100 of the April issue of Control Engineering, I would like to make a suggestion. I believe that you should cover in your magazine the Bendix Three-Dimensional Flight Simulator. A picture of the Flight Table associated with this equipment appears in the March 19 issue of *Time* magazine on page 101, lower right. The Flight Table shown there represents one of

THE PROBLEM FORUM

This month one reader submits his answer to our semantic April Fooler on the suggested word "feedforward". Another reader requests help in locating equipment for a measurement problem.

Try your hand. Send in your answer to problems we've printed recently, or submit your own measurement or control problem to our readers (and the editors, too). We will pay for either communication, if published.

1. Semantic answer

To the Editor—

Having read your "April Fooler" (Control Engineering, April 1956, page 6), I would like to suggest the word "prefeed" instead of your "feedforward". "Feedforward" is quite a mouthful.

"Prefeed" could mean—"a sensing prior to control correction" in the same manner that "feedback" is—a sensing subsequent to control correction.

John F. Flanagan
United States Rubber Co.,
Mishawaka, Ind.

2. Equipment query

I should welcome your advice on an instrumentation problem I have. I wish to measure both static and dynamic pressure fluctuations up to 3,000 psi. In Britain I have used an instrument in which the pressures to be measured were applied to a diaphragm. The diaphragm formed one plate of a parallel plate condenser and the deflections of the diaphragm resulted in a change of capacity. This change in capacity varied the frequency of an oscillator. By various means the change was presented on an oscilloscope.

The response of the instrument is limited only by the mechanical response of the diaphragm. I have found this type of instrument useful up to frequencies of 1 kilocycle/second. Could you please suggest an American counterpart?

R. A. B. Wilsher
Air Armament,
Canadian Westinghouse Co., Ltd.,
Hamilton, Ontario

the most advanced simulation tools in existence today. The design and performance capabilities lead the field in electronic-hydraulic control.

It may interest you that there are two Flight Simulators in existence at this time. One of them is located in Detroit, Mich., and is being operated by Bendix for the BuAer, U. S. Navy; the other is located at Holloman Air Force Base, New Mexico, and belongs to the Air Force. A third model has recently been ordered by a major aircraft company.

Joachim Kaiser Jr.
Detroit, Mich.

. . . you'll get that article very soon.

But in the meantime, you'll find in this issue an Idea-at-Work (page 119) describing a small solenoid-driven "flight table" designed to test aircraft instruments. Ed.

NICB report in demand

To the Editor—

In your May 1956 publication of Control Engineering an editorial on training opportunities, namely "Improve Your Investment", page 61, was published.

We are very interested in obtaining one copy of the NICB study titled "Tuition-Aid Plans for Employees" mentioned in this article as released to NICB-associated companies and available through their libraries.

Since we may not fall into the category of "associated companies" we feel we may have some difficulty in obtaining or procuring this study on tuition aids. It is our intention to incorporate a training program in this company and any information or publications available, such as the beforementioned study, would certainly be a valuable asset to us.

W. J. Baer,
Farris Eng'g Corp.
Palisades Park, N. J.

Normally the NICB reports are released only to members (associates) of the board. Nonmember companies should contact NICB headquarters, 247 Park Ave., New York City, for information. Ed.

Boola boole-an algebra.

Consulting Editor E. M. Grabbe

FEEDBACK

stated in his article, "Data Processing Systems: How They Are Used", CONTROL ENGINEERING, Vol. 2, No. 12, that "the West Coast leads the East Coast in logical design". Letters flew from loyal Easterners. Here is one of his rebuttals. We think it is interesting commentary.

"I agree with your remarks regarding the misuse of the term 'Boolean algebra'. It would probably be better to state that Boolean representation is used in logical design. In any case, the difference between West Coast and East Coast procedures which are referred to might be described as follows:

"West Coast computer designers tend to design complete computers in equation form, without the use of block diagrams or flow charts. In the East it is still common to work from block diagrams in computer design. Members of our staff who have worked on logical design using both approaches are unanimous and emphatic in their statements that more efficient designs can be produced by equation design. They claim it is easier to catch mistakes in logic, and changes in design can be easily incorporated."

Proceedings to come

TO THE EDITOR—

In the October 1955 issue of CONTROL ENGINEERING we have read on pages 28-30 your report of the Western Electronics Show and Conference. Especially some words about a session on nonlinear servomechanisms, sponsored by the IRE Professional Group on Automatic Control, have drawn our attention, as we at the Technological University of Delft are working in this field.

We would appreciate it very much if you would be so kind to tell us where the mentioned five papers are available.

Ir. B. P. Th. Veltman
Laboratorium voor Technische Physica
Der Technische Hogeschool
Kanaalstreat 12
Delft (Nederland)

CE Consulting Editor E. M. Grabbe, Chairman of the session described, advises that the papers presented at the session will be published in the "Proceedings of the IRE-PGAC". Ed.

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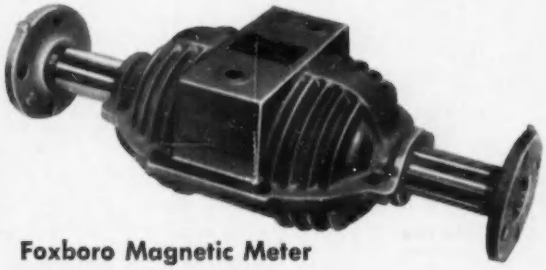

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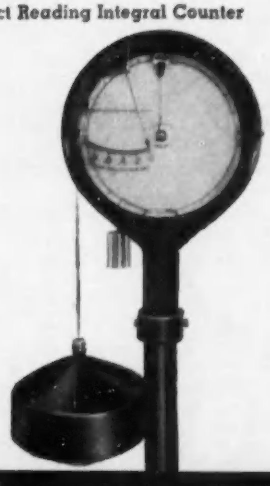

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RALPH D. WEBB
cultivates his field

When asked what has been his most satisfying contribution in 30 years of pioneering industrial instrumentation, trim, youthful-looking Ralph Webb unhesitantly replies, "Helping cultivate a crop of young people in this field."

Ralph could name a dozen things any engineer would be supremely proud of. He could tell of prime-moving the largest process control project of the war. Or he could describe his fruitful work, 25 years ago in Tulsa, in what has become one of the liveliest new fields of measurement: chromatographic analysis. But he would much rather dwell on the 140 enthusiastic technical men—from "home grown" engineers to PhD's—who now make up Carbide & Carbon Chemicals Co.'s Instrumentation Div. "Cultivating this group," Carbide's director of instrumentation says, "is really my life's work."

In his formative years Ralph Webb could have used some of the career guidance he gives others today. Born Oct. 30, 1897, in Alton, Ill., he spent his teens "tinkering" in his dad's boatbuilding machine shop on the banks of the Mississippi. Early in 1918 he enlisted and became the "only army company commander who never fired an army rifle." "I did fire a machinegun, though," admits Ralph. "It seems my reflexes were so fast that they used me to demonstrate this weapon at Camp Hancock by shooting one bullet at a time to conserve precious ammo." Anyone who rides with Ralph behind the wheel of his Nash today knows that he preserves those famous reflexes.

Out of the Army early in '19, the ex-shavetail joined Standard Oil as a "human actuator" on its coal-fired still at Wood River, Ill. This primitive combustion control served to kindle a career: "I decided it was time I went to college for a more scientific approach to the subject." At the University of Illinois the spirit that boosted him through the Army brought him a BS in ME in '24, and membership in three honorary campus engineering societies. Three weeks after he joined the newly formed Carbide & Carbon Chemicals Corp. in its Prestone plant in Clendenin, W. Va., he was in Tulsa working with a test group in the early field application of Carbide's new gasoline stabilizer. During this period he devised a simple but very workable instrument system to identify unknown hydrocarbon components (a technique now known as chromatography). In '29, his reputation already established in measurement, Webb helped start up a new methanol plant in Niagara Falls and later became assistant superintendent.

Ralph Webb's goal started to materialize in September 1933 when he went to the big new plant in South Charleston and took over its six-man meter department. In 1936 he got a "refreshing jostle" by spending a week with C. E. (Doc) Mason and absorbing some of this pioneer's philosophy on the dynamic approach to control systems engineering. A year later he was writing about this fast developing art: a Webb article in *Instruments* traced the history of rate action and put Ralph in the uncomfortable position of being quoted in a famous controversy between two instrument manufacturers. His department's first big job was the new Texas City plant in 1940. Then, during the war, he headed the group that created, during nights and weekends, the eleven famous ballroom-sized control rooms that ran butadiene plants at Kobuta, Pa., Institute, W. Va., and Louisville, Ky. After V-J day Carbide's director of instrumentation added a special Instrument Development Group and built up what is now recognized as one of the finest industrial instrument departments in the country (a near-future issue of CtE will describe it in detail).

The screwdriver in Ralph Webb's hand and the complex chromatographic research apparatus in the background typify the "seed and the fruit" of his 30 years at Carbide.

In off-hours Ralph is active in societies—he helped start IRD and ISA, also belongs to AIChE and AAAS. His big hobby is vegetable gardening and growing prize-winning tomatoes staked out on old thermometer wells. He and his wife Leone, an Alton girl he went home to marry in 1926, recently bought a beautiful four-acre hilltop and will soon vacate their charming Cape Cod for "the experience of living in a glass house". There, practically inside his living room, Ralph Webb will cultivate his plants while mentally harrowing another more important crop four miles away over the hills.

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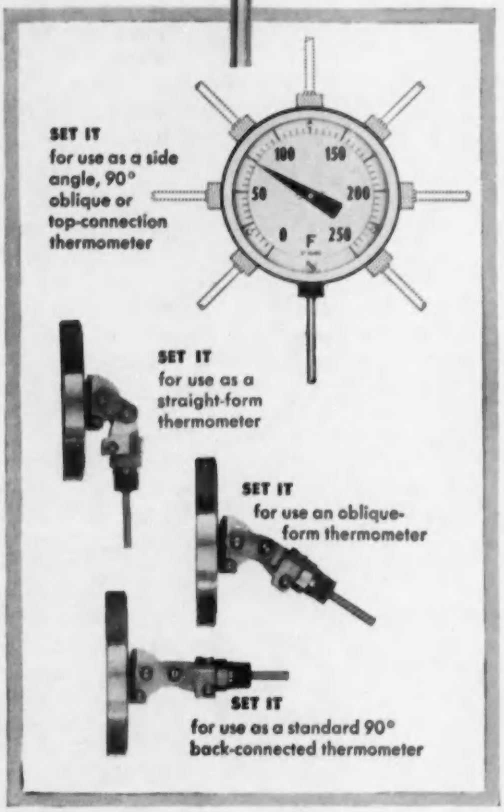
*Pat. App. For



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5-Inch Type 5-6060 American "Every Angle" Bi-Metal Dial Thermometer

Temperature Ranges: From minus 80° to plus 1000° F. Accuracy within 1% of range. *Dial Size:* 5". Scale approximately 10½" long. *Bi-Metal Coil:* Low mass, with single helix close to inside wall of stem assures high sensitivity. Silicone fluid dampens vibration, accelerates transfer, speeds response. *Case:* Stainless steel. *Bezel:* Threaded to case. *Front:* Clear, extra-heavy glass set in channeled gasket to seal case. *Pointer:* Functional type, adjustable from front. *Stem:* Lengths — 4" to 24", 18-8 stainless steel. All joints welded. *Connection:* Fixed, ½" NPT. *Separable Sockets:* Available in all materials and sizes normally required.

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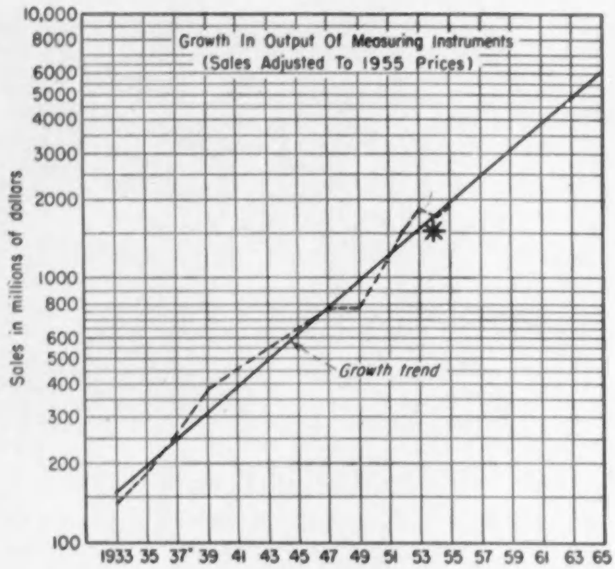
UNIVAC churns it out . . .



. . . and the incredible slopeline is again proved.

Instruments Census Exceeds Expectations

WASHINGTON, D. C. May 15—The first official collated information in seven years is substantiating suspicions about the growth of the control products manufacturing industry. The data, which come from the U. S. Bureau of the Census as part of the 1954 Census of Manufactures, show, among other things, these remarkable gains over similar Census figures that appeared in '47:

- ▶a growth in sale of process control instruments from \$168 to \$271 million
- ▶an explosive rise in autopilot control systems from \$20 to \$378 million
- ▶a climb in time controllers (electric and spring) from \$13 to \$25 million
- ▶a burst in control equipment from \$100 to \$259 million

Many market experts who closely followed the snips and bits of sales information from other Dept. of Commerce reports and from private agencies such as SAMA, McGraw-Hill market studies, and field journals, predicted such growth (in January, page 45, CtE, reported on a McGraw-Hill estimate of 50 per control field growth during the next five years). But few were bold enough to approach the actual figures, which appear in this month's *Industry's Pulse*, page 61.

GE Analyst Scores a Bullseye

One man who got close was H. C. Dickinson, an engineering administrator in General Electric's Instrument Dept. To the job of surveying the growth and potential of the measuring instruments industry, Dickinson brought a knowledge of his market and an engineer's approach. The result was an accurate updating of a predicted growth curve, based on past data, to the current price level. The key Dickinson chart, shown above, indicates that the field keeps growing at an exponential rate and has averaged an annual increase of 12 per cent over the past 23 years.

Dickinson was almost "right on the nose" as far as the '54 data were concerned—his estimated growth: to \$1.7 billion; the actual growth: to \$1.8 billion. And if his accuracy persists, there's incredible growth ahead. Extrapolation of the curve indicates industry sales of \$3.4 billion by 1960, based on '55 prices (well above that "conservative" 50 per cent growth estimated by McGraw-Hill); and on up to an astonishing \$6 billion by 1965.

An assay of Census data in the Instrument Industry categories is hardly, of course, a complete picture of sales of all measuring devices that fit the control loop; or an all-encompassing view of the total field of instrumentation and automatic control (see *Editorial*, page 67, for comments). But they are the only good available data and, if studied, suggest the complete outlines of a field. In his analysis, Dickinson stressed this point. He selected his data from three major Standard Industrial Classifications, the official Dept. of Commerce groupings: Electrical Measuring Instruments, SIC 3613; Scientific Instruments, SIC 3811; Mechanical Measuring Instruments, SIC 3821. A brief description of how he arrived at his conclusions is on the opposite page.

UNIVAC Spurs the Census

Besides reaffirming the vigor of the control field, the 1954 Census of Manufactures provided the means for this new technology to score still another triumph: it was the first big Census and public information job to be completely handled by electronic data processing and UNIVAC. The results are pleasing both engineers and economists. Data have moved through the system much faster, more precisely, with more collation, and with far less error—and they have reached industry while still useful.

As computer historians know, Census funds were responsible for creation of the first famous UNIVAC by Eckert and Mauchly in 1947, and (see picture above) it went into the big building in Suitland, Md., in 1951. Its first job was to partially process the then-in-progress 1950 Census of Population. Two years of experience

HOW GE's DICKINSON FIGURED IT:

HIS RAW DATA

(Growth of Instrument Industry in Millions of Dollars)

YEAR	ANNUAL SALES	SALES ADJUSTED TO 1955 PRICE LEVEL
1933	48	142
1935	75	183
1937	122	266
1939	169	385
1947	633	767
1949	646	765
1950	825	930
1951	1,171	1,160
1952	1,508	1,550
1953	1,773	1,843
1954	1,676	1,705
1955	1,874	1,874

Note: Figures for years '49-'55 based on non-Census estimates

"The sales shown for the years '37-'53 were obtained directly by totaling Dept. of Commerce data on the value of products shipped for the three SIC instrument classifications (see news story—Ed.). The 1933, '35, '54, and '55 figures were estimated based on production indices for broader groups that include the three classifications. The '54 and '55 estimates are tentative and subject to revision as more detailed information is provided by department publications.

"The above data arranged in graph form strongly suggest an exponential growth rate. This is confirmed by the straight-line growth trend obtained when the sales data adjusted to '55 prices are plotted on a semilogarithmic scale. Further analysis of this trend by utilizing the equation for the trend line leads to interesting conclusions concerning the growth rate and probable future size of the measuring instrument industry.

"The general equation for the trend line is:

$$\log_e \frac{S}{S_o} = kt, \text{ or } \frac{S}{S_o} = e^{kt}$$

where S is the dollar sales in any one year at 1955 prices, S_o is the dollar sales at 1955 prices in the initial year, t is the time interval in years between S and S_o, and k is a rate of growth constant defined by the slope of the semilogarithmic trend line.

"For the trend line (see graph—Ed.), $k = 0.1142$ per year. Substituting this value of k in the equation above and solving for the condition of $t = 10$, the result is $S/S_o = 3.13$. This shows output more than tripled every ten years.

"For $t = 1$, the value of $S/S_o = 1.121$, or an increase in the output each year of 12 per cent over that of the preceding year. This yearly per cent growth rate compounded annually for ten years equals 213 per cent, which is the same as the 3.13 times growth every ten years just calculated.

"Letting S_o be the trend line for 1933, or $156 million, and solving the equation for S in the year 1965, results in a value of sales for that year of $6 billion. This will, of course, depend on the annual per cent growth rate and the present price level being maintained. Similarly, the result for 1960 is $3.4 billion, or an 80 per cent increase over present output. Values for intervening years may be similarly calculated."

suggested the need for a second UNIVAC in the Bureau, and at the start of 1955 number two began to process the Manufacturers Census data which were just starting to come in. Since that time both UNIVACs have operated 24 hours a day, seven days a week, and two more rented units are serving the bureau in Pittsburgh and on the West Coast.

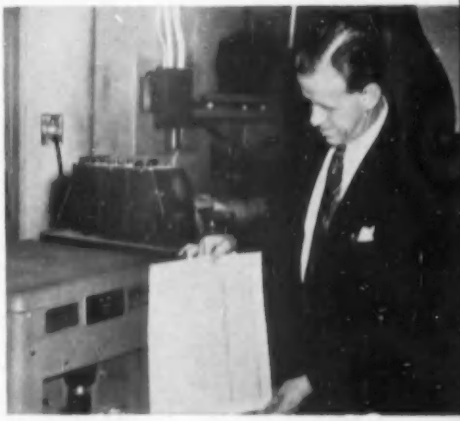
If one wonders why four of these powerful machines are needed to handle one job, he should consider that the work involves reports on 450 industries and more than 3 million establishments—certainly the largest single data-processing job in the world.

Simplifying the Job

Know-how in applying UNIVAC should cut down the need for such great computer capacity in the future. For one thing, tricks of self-checking data have developed (i.e., comparing figure values against expected range to spot a decimal error) which curb corrective reruns. But the big area of improvement is expected to be in input and output devices, whose faster speeds may start to match the huge, only partially used computing capacity of the machine. Much of the research work toward this end is being done by engineers at the Bureau of Standards. But help also constantly comes through new commercial equipment. Examples of the two sources are shown in pictures at the right.

INPUT TO UNIVAC:

J. L. McPherson of the Census Machine Development Office displays the Fosdic form, which will permit an optical read-in of information. The machine on his right, Film Optical Sensing Device, scans a microfilm copy of the filled-in form—which holds information by the position of a mark rather than by conventional letters and digits. Developed at Bureau of Standards, eight of these devices operated by 100 people are expected to do the work of 2,000 in speeding data in the 1960 Census.



OUTPUT FROM UNIVAC:

The young lady is standing by a new high-speed printer that was recently furnished by Remington Rand to expedite the '54 Census. It is capable of printing 600 120-digit lines per min and includes a flexible plugboard method for programming the printing operation. An interesting characteristic of this printer is its ability to turn out information on X-Y coordinates direct from raw data. A recent timely project: producing a chart of seasonable adjusted farm income.

CONTROL CONCLAVES

Detroit, May 16

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A "BREAK" IN BOSTON

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VOLTAGE REGULATED POWER SUPPLIES

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★ ***GOOD*** **STABILITY**

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RIPPLE: Less than 3 mv. rms.

STABILITY: The output voltage variation is less than the regulation specification for a period of 8 hours.

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All models available for 400 cycle operation on special order.

1.5 Amp. KR SERIES

Model	Volts	6.3V AC	Rack Mount W	H	D	Price
KR16	0-150	Each supply	19″	12¼″	17″	$625
KR17	100-200	has two	19″	12¼″	17″	$625
KR18	195-325	15 Amp.	19″	12¼″	17″	$695
KR19	295-450	outputs	19″	12¼″	17″	$695

600 ma. KR SERIES

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KR 8	0-150	Each supply	19″	10½″	13″	$330
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KR 3	100-200	has two	19″	7″	11″	$180
KR 4	195-325	5 Amp.	19″	7″	11″	$180
KR 10	295-450	outputs	19″	7″	11″	$190

125 ma. KR SERIES

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KR 2	195-325	3 Amp.	19″	7″	7½″	$ 90
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WHAT'S NEW

digital form. Normally he must receive and pass out digital info serially. An exception is his playing of an organ; then his output (digital also) is parallel. Perhaps, then, developers of data systems that include a human should study how he plays an organ. This might lead to easing the bottleneck caused by the human's serial input and output.

"Carl Spaulding of Giannini's Datex Div. described how telemetering equipment arose in telephone systems and in transmission of military test data. Shannon's theoretical treatment is the foundation of present-day practices of optimizing information per channel. The equipment and practices are headed for industrial use, said Spaulding. But he thinks that the biggest roadblock will be removed when coding, multiplexing forms, and resolution are standardized.

"George Shaw, Radiation, Inc., described how ultra-high-speed telemetry was developed for nuclear-weapons tests: Crossroads, Teapot, and Greenhouse. Now the Radiation AKT-14 has evolved to handle 21,000 bits/sec per channel. It records data on magnetic tape so fast that lumberjacks could not possibly cut down trees fast enough for the manufacturers of cards for storing the equivalent data (he claims). He mentioned that a 'quick-look' recorder will soon be available that will record and edit these data as numbers. Needless to say, when George got through, his industrially-oriented audience was shaken—and head-shaking. They did, though, show great interest in the 'quick look recorder' idea.

Editing in Data Processing

"Bill Keene, CEC, emphasized the need for editing by pointing out that no more than one to five per cent of recorded data is actually used after a test. To ease the editing, data processors have become automatic: they use magnetic tapes and some type of direct-writing oscillographs for intermittent recording or for that informative 'quick look'.

"During the banquet that night Dr. John Grabe of Dow Chemical gave an enthusiastic talk called 'Horizons in Instrumentation'. His point of view was a broad one, unconfined by the fences of specific engineering classifications. He demonstrated a 'cornucopia' of instrumentation, a printed chart which shows the frequency range of natural phenomena and the small portion covered by man's senses."

"The following day," Lloyd Slater

WHAT'S NEW

reports, "got down to applicational brass tacks. Fred Hannula of Foxboro started things off by describing

Foxboro's Fred Hannula

a special Btu computer his company devised to automatically control the rate of heat transfer in a nuclear process. The unit consisted of familiar instrument components: a combination of a flow transmitter with a differential temperature recorder equipped with a basic Wheatstone bridge. But it was obvious that functional elaboration of this combination would set the thing up to control fairly complex unit processes. In other words, what Foxboro unveiled was a small but significant step in the direction of developing the specialized analog control computers (black boxes) which are demanded by the 'visionaries' as the 'missing links in the automatic factory'.

"Next, W. P. Hamilton of Leeds & Northrup stood up to tell about

L & N's Hamilton

the system his company developed to handle wind-tunnel data. Once again the analog-type recorder—in this case the L&N Speedomax—proved to be the basic measuring instrument. He described two installations: one at Langley Field, with a 1-30-channel logging setup; and one in the Boeing Transonic Tunnel with 12-channel logging. It was obvious that L&N has delved deeply into the digital-techniques field and has developed engineering talent capable of tackling advanced data systems. Further, that the company is building excellent numerical display equipment. But the systems cited were not exclusively L&N-equipped: at least three other major suppliers furnished such items as the transducers, translators, and readout equipment. This surely demonstrated the amount of 'inside' industry selling that goes on before a major

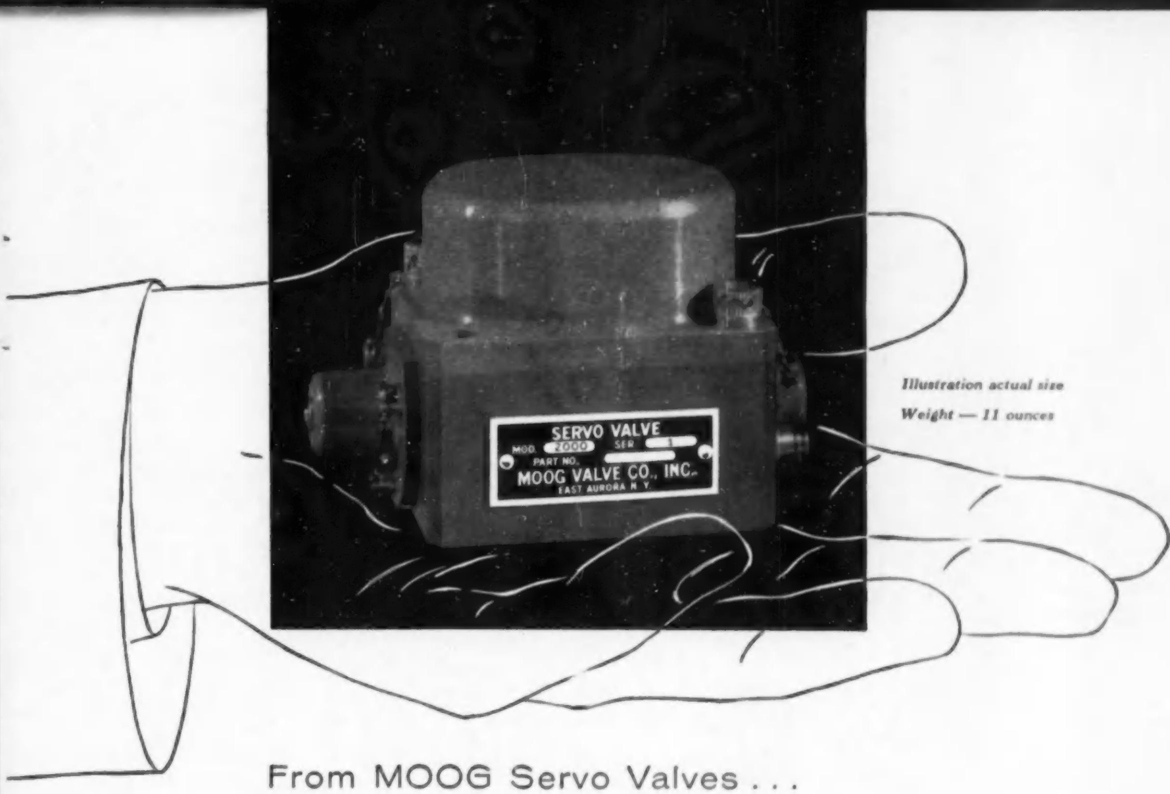


Illustration actual size

Weight — 11 ounces

From MOOG Servo Valves . . .

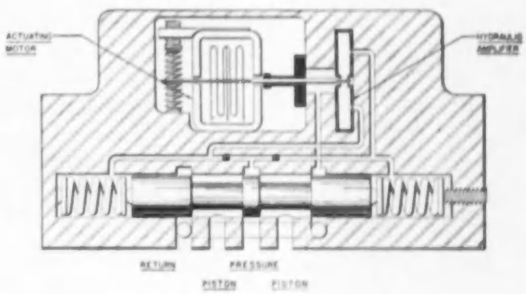
High Accuracy and Response

One of the outstanding characteristics of Moog Servo Valves is their exceptionally high dynamic performance. Moog units are characterized by equivalent time constants as low as one and one half milliseconds from input differential current to output flow.

Performance of this magnitude makes possible control systems of high accuracy and response. Typical applications for these valves are in servo systems of advanced aircraft and guided missile flight controls, radar scanner actuation, contour following machine tools, and automatic packaging equipment.

Conventionally, valve input is from a balanced push-pull DC amplifier and valve flow output is applied to a piston or hydraulic motor. An electric signal proportional to piston position or motor angular rotation is fed back to the amplifier to give a closed servo loop.

Production models are designed to operate in hydraulic systems of from 1000 to 3000 PSI pressure. Rated output flow from 0.1 to 50.0 GPM, for control currents between 2.0 and 40.0 milliamperes as specified, are available in production units.



For details write for Bulletin 2000-2

MOOG VALVE CO., INC. PIONEER AIRPORT EAST AURORA, N. Y.

vendor can offer a 'packaged system'.

"The most eagerly-listened-to paper seemed to be the one presented next by T. M. Vick-Roy of du Pont—probably because this company was one

duPont's Vick-Roy

of the few users of data-processing equipment on the program. Vick-Roy satisfied and startled the boys by reeling off a cost comparison between four basic methods of gathering data:

Cost Per Point	
Automatic logger	\$300–\$600.
Multiple recorder	\$100–\$200.
Miniature recorder	\$150–\$250.
Pneumatic recorder	\$100–\$250.

His point: the need for displaying data must correlate with the dollars and cents value received—hence, one must look at a per-point price as well as the technical intrigue of advanced design. Vick-Roy also stressed that reliability is the major problem as far as his company's approach to data processing is concerned. He pointed out that a process plant is no 'aircraft' and that data must come in precisely over a long period of time.

"In the afternoon Russell Aikman of Schlumberger Instrument Co. stood in for Bert Ziebolz, Askania Regulator (Bert had just left on one of his periodic European junkets the day before). In his wry Scotch brogue, Aikman read a Ziebolz paper describing the now-famous Two-Time Scale approach to automatic control. Essentially this method involves setting up a fast-time analog of the real-time process, including it in the process-control loop, measuring its response to a controlled signal, and feeding back to reset the process controller as an anticipation of change. Through Aikman, Ziebolz stressed that this was simply a 'line of attack' . . . that much work must be done in dynamic analysis and in using such techniques as Reswick's 'delay line synthesizer' (see CtE, June '55, p. 50) before even this simple experimental approach can be exploited. The discussion that followed extracted, as was expected, some good comments from some of the 'old pros'

of process control (i.e., Bob Jeffries, Nate Nichols, Mead Bradner).

"Nate Nichols, Raytheon Mfg., buttoned up the two-day program

Raytheon's Nichols

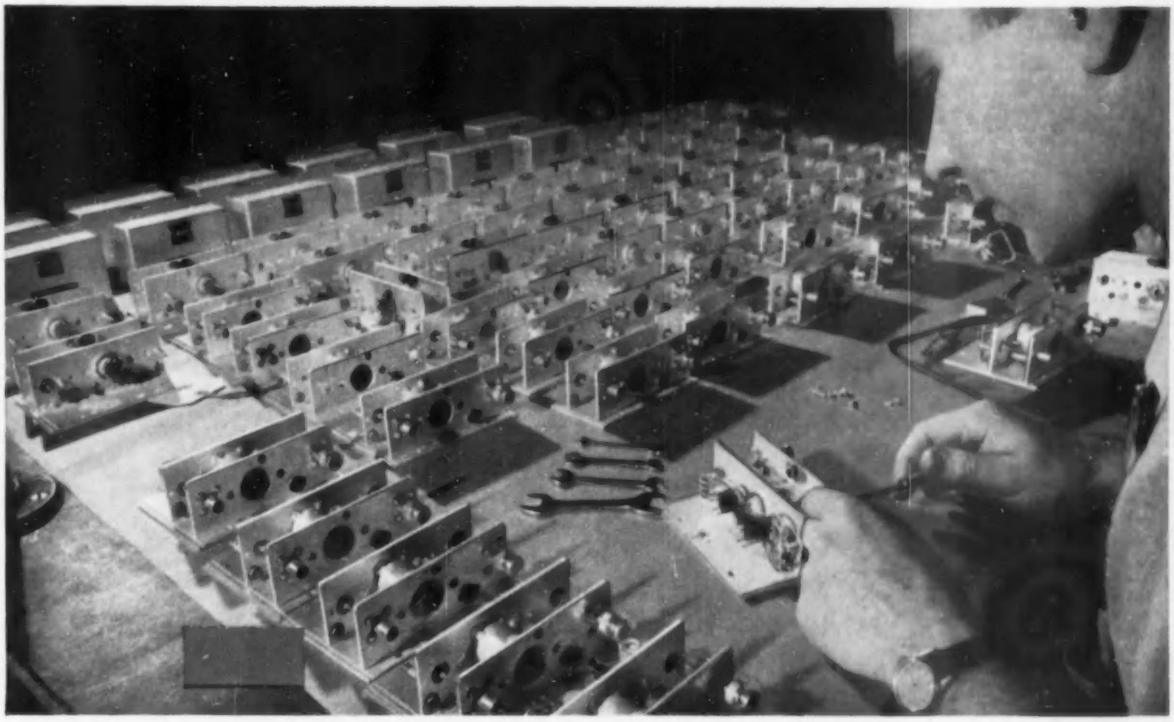
with a discussion of the virtues of solid-state devices—mainly transistors—in computers and control instruments. Most of the 500 registrees sat right through to Nate's talk before heading back to plants—mainly control equipment manufacturers—all over the East Coast and as far west as Chicago. Some, however, stayed over to see the Yankees blast the ball out of Fenway Park on Saturday."

Buffalo, April 17-18

Once again our machine control specialist, Byron Ledgerwood, hied up to Buffalo to take in Westinghouse's annual Machine Tool Forum. "This year's," says By, "was the 20th annual forum, and the biggest and best yet. Attendance was about 600, including representatives of all of the important machine tool builders. The first session was devoted to numerical control of machine tools. After Lou Herchenroeder of Westinghouse introduced the topic, there were detailed descriptions of the Binotrol system by Dave Smith (Jones & Lamson), the IBM cam miller by Mark Morgan, and numerically programmed discrete positioning systems by Marshall Brittain of Westinghouse.

"The new machine-tool electrical standards were presented by the National Machine Tool Builders Association. As in the past, these were devoted primarily to the electrical problems encountered with conventional industrial control equipment of the heavy-duty-relay and motor-starter variety. Because of incoming complex electronic control and programming systems, there was some question as to whether the standards should be revised soon to take in this new equipment.

"The significance of the new NEMA standards for dc industrial motors was covered by M. E. Knudsen of Westinghouse. His major point: the recognition of the dynamic



characteristics of dc motors and the fact that most are being used on variable-voltage drives with their own generator sources. Since it is believed that many of these adjustable-speed dc-motor applications will be rather 'special', no standard frame sizes are now assigned to these motors. The use of Class B insulation plus a longer core length for a given armature diameter reduces mechanical inertia materially and improves motor response. In addition, the new designs have a slightly lower time constant for the main field, but this is not significant compared to the degree in mechanical inertia.

"The morning of the second day was devoted to progress of CYPAK over the past year and introduction of the new encapsulated units (CtE, May, p. 26). Glowing success stories on the application of CYPAK were given by representatives of Ford Motor, General Motors, and Chrysler. Although the experience of each group has been limited to one or two CYPAK-equipped machines, the reliability has been excellent (with failure of rectifiers only), and the production cycle time has been reduced materially. The Canadian Westinghouse Co. introduced highly accurate inductive-type linear position-measuring elements directly aimed at the machine tool field."

Milan, April 14

Last month (CtE, June, p. 27), we briefly described the international symposium on "Automation", held in Milan, April 8-13, and promised a more detailed analysis by John Hrones of MIT. John sent on the proceedings, "which speak for themselves", and remarked that "the exhibits connected with the fair were small and essentially devoted to well-established equipment in the telephone industry. Fiat also had a major exhibit, automotive in character."

John went on in his letter to describe his wanderings in the Milan and north Italy area, a "bonus" report well worth study by the control engineer. "I visited," he writes, "a small resistor factory in Milan and the large Olivetti plant in Ivrea, just north of Turin. I also talked with some Italians at the conference and elsewhere As you know, the industry of Italy is concentrated in the north in the Miland, Turin, and Genoa areas. Hence the picture one gets in Milan and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COIL DRAIN: Approximately .080 Amperes at 115 Volts, 60 Cycles
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NEW 25 AMPERE POWER RELAY
by GUARDIAN®
Built to Meet U/L Specifications
Control more power in less space with this new Guardian 25 AMPERE A.C. Power Relay for motor starting, heater loads and other heavy duty applications. Standard unit has double pole, double throw contacts rated at 25 amperes continuous duty, 230 volts A.C., with 75% power factor. Operating power requirement is 9.5 VA.; coil drain approximately .080 amperes at 115 volts, 60 cycles. Two easily accessible screws permit removal and replacement of completely *interchangeable* coil assemblies rated at 6 V.—24 V.—115 V. or 230 V., A.C. Relay measures 3⅜" x 2½" x 2³⁄₁₆", weighs 11 oz.
Write for Circular describing Guardian's New Power Relay. Request bulletins on Guardian Relays, Steppers, Solenoids and Switches.
GUARDIAN'S 25th YEAR
GUARDIAN ELECTRIC
1623-H W. WALNUT STREET
CHICAGO 12, ILLINOIS
A COMPLETE LINE OF CONTROLS SERVING AMERICAN INDUSTRY

WHAT'S NEW

Turin is the brightest side of Italian industry.

"Milan, 80 per cent of which was damaged during the war, has been almost completely rebuilt. It demonstrates drive and energy and an ability to produce. Other than isolated plants, it is the first city I have seen in moving from Turkey west which gives the impression of having a series of strong, well-rounded production industries.

"While evidence of domination by single large companies is everywhere—Fiat, Olivetti, Motto, etc.—there are also numerous strong, young outfits doing very well. Nevertheless, automation, in the terms in which we think of it, is barely started. For example, Olivetti, despite its excellent machinery, does an amazing amount of hand work and would be a paradise for the American production man. Some of this is due to the low wage scale which, although many times higher than before the war, is still low compared to ours. An average production worker's hourly wage is of the order of 150 lire (25 cents) although, just as in our country, social security, health plans, paid holidays, etc., give fringe benefits. A Fiat automobile costs about \$1,800, gasoline about 70 cents a gallon. A good meal in a restaurant runs about 80 cents. This may give you some measure of the standard of living in the north.

"The Italians are much interested in talking about automation, but I would say are a long way from considering it as we do. There are reasons for this, some good, some questionable: 1) the labor situation already discussed—incidentally, there is a very large source of low-cost labor in southern Italy; 2) their markets are small and diverse and lend themselves to small-lot runs. They inherently believe that real accurate work—such as is involved in making a typewriter or calculator—must be done by hand. They believe that practically all inspection must be done directly by men or women. Actually, in certain small-lot production and in many of their inspection problems, one can see great possibilities for automatic techniques. Incidentally, Olivetti is just coming out with a new calculator—a competitor to Monroe and Friden."

After filing the above, Dr. Hrones headed for sunny southern France and busy, productive Switzerland. We look for his comments on Swiss precision work, perhaps in the next issue.

WHAT'S NEW

Rear Adm. F. L. Hetter, Commanding Officer of ASO, proudly demonstrates one of the magnetic-tape data-storage units in the IBM 702 system that his base successfully uses in world-wide inventory control. The onlooker is Rear Adm. R. J. Arnold.

Navy Digitizes Its Air Supplies

PHILADELPHIA, May 22—Chalk up a 21-gun salute for the officers and technicians at the Navy's Aviation Supply Office. In their huge, brick, suburb-ringed facility here, they have been quietly perfecting what is perhaps the world's largest—and certainly its most successful—digital inventory control system. Just a few of its functions:

- ▶ keeping track of 450,000 separate items
- ▶ covering 63 different shore-base locations
- ▶ cutting order time for parts by 50 per cent thus far
- ▶ providing "management" reports for: planning procurement ahead by as much as three years; cataloging parts lists; scheduling worn parts maintenance

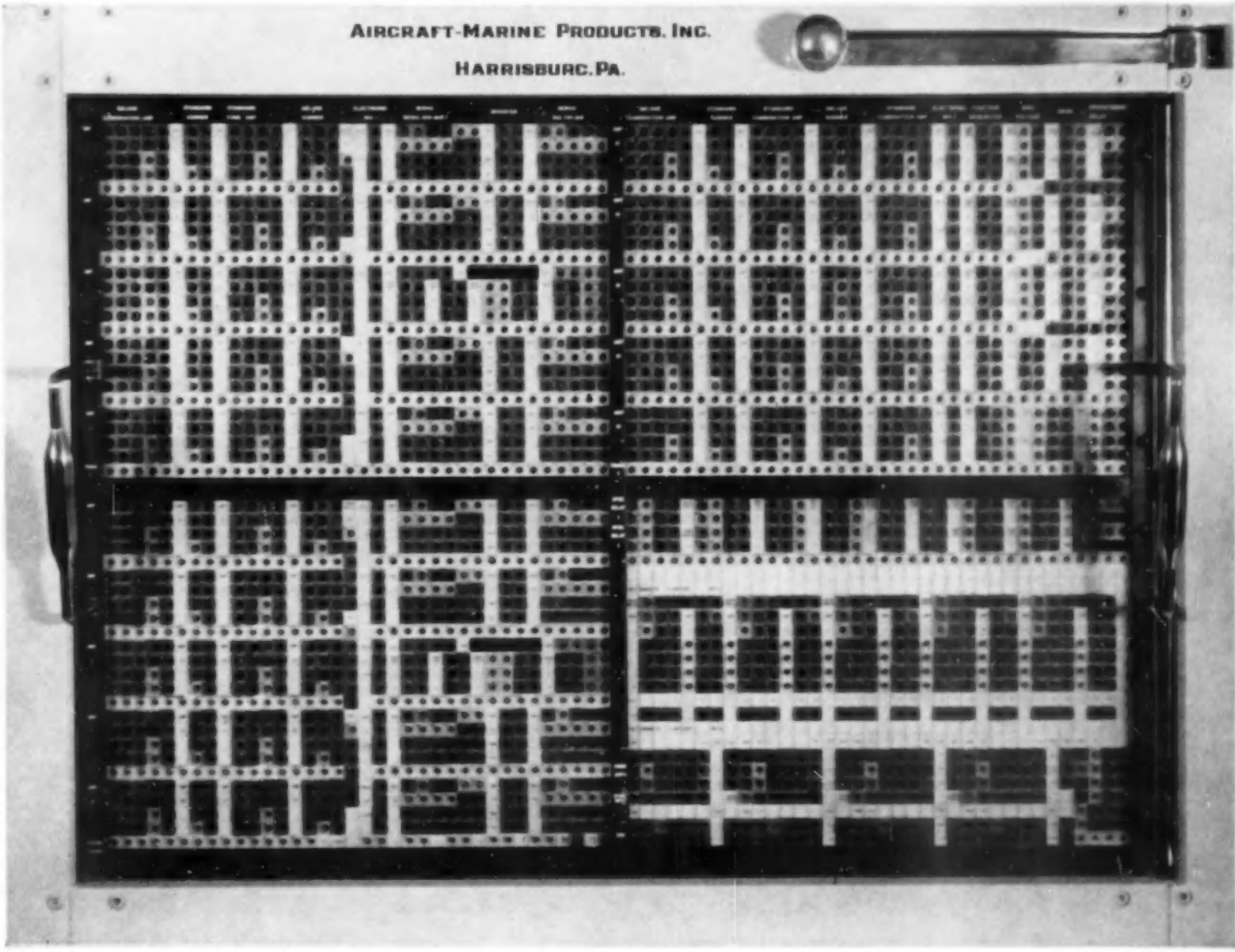
A Magazine Article Started It

Once the Navy got the idea it didn't spare the knots in pushing it along. It originated back in 1949, when an officer at the base scanned a magazine article on electronic data processing. A terse note, "We could use this," started the problem toward the National Bureau of Standards, where Samuel N. Alexander (CtE, May, p. 87) directed development of the prototype system. Next a contract was placed with IBM for one of its first 702 machines. It was delivered 28 months ago and, although positive results came almost immediately, Base Commander Admiral Hetter wisely let the project coast into reasonable maturity before officially unveiling it to the press.

"Not One Delinquent Report"

Stock-report information now comes in from far-flung bases by letter—although 14 main locales will soon be hooked up directly to ASO by transceivers. The data is converted to punched cards and these are read into tape storage. The 702 then draws its data from a vast tape library as well as from rapid-access magnetic drums, collates and/or computes, and reels out the reports on high-speed printers. And as Admiral Hetter proudly says, "Today there is not a single delinquent report on board this station."

Just as impressive as the system are the enthusiastic, articulate young officers and men who run it. Their pride in saving the taxpayer incredible sums of money is great, of course, but it can't compare with the pride that comes through pioneering in a difficult technology. They have forged a logistics weapon that could well be the nucleus of a giant EDP system for controlling materials into and through all the armed services.



THE NEW AMP CELLULAR, SHIELDED PATCHCORD PROGRAMMING SYSTEM

Important Moves by Key People

▶ Several MIT engineers, led by **James O. McDonough,** have left the Servomechanisms Lab to open their own business in Cambridge, Mass., under the name of Concord Control, Inc. Most of the men have played prominent parts in the development of numerically controlled machine tools in the lab. McDonough, for example, who had been a project engineer there since 1951, helped with the design and construction of the first milling machine to be completely controlled by digital techniques. He joined MIT in 1946 to work on special dc servomotors and generators as well as on the instrumentation and control of the Brookhaven National Laboratory's nuclear reactor. Other officers of Concord Control, besides President McDonough, are **Herbert P. Grossimon,** vice-president for engineering; **Richard W. Lawrie,** vice-president of sales; **Robert H. Gregory,** comptroller and treasurer, and **Charles M. Ganson,** clerk.

▶ With the appointment of Vice-President **Alfred J. Pote** to director of engineering of Hycon Eastern, Inc., **Dr. Howard W. Boehmer** moves up to fill Pote's former position of chief engineer. Pote, who came to Hycon from MIT's Lincoln Laboratory, where he had been head of the Communication System Design Group, moved up fast: he only joined Hycon last July. While at MIT, he designed equipment for high-powered radio-frequency sources, designed, built, and operated the first television transmitter in New England, and contributed to the Loran direction-finder. He is the inventor of the saturable-core voltage regulator. Boehmer has not lost much time, either: he came to Hycon just recently as assistant to the vice-president. Another former Lincoln Lab man, he was in charge of the System Analysis & Evaluation Group there. He also has been a research physicist for Stromberg-Carlson Co. and an associate professor of physics at the University of Colorado.

▶ Another fast riser is **F. J. Gaffney,** whose election as vice-president for engineering of The Teleregister Corp. follows his arrival at the company by barely a year. He previously served as director of engineering for Fairchild's Guided Missiles Div. and as general manager of The Polytechnic Research & Development Co.

▶ **Edward S. Ruth** has replaced **Frank R. Bridges** as chief engineer of The Gamewell Co. Bridges has resigned. Ruth, who was director of research, engineering, and development for Edwards Co., Inc., before coming to Gamewell in 1954, is chairman of the technical committee of the National Electrical Manufacturers Association.


J. O. McDonough


H. W. Boehmer


F. J. Gaffney


E. S. Ruth


J. H. Howard


M. B. Prince

R. B. Cory

J. A. F. Gerrand

Oliver Simms Jr.

►From his headquarters at Underwood Corp.'s General Research Laboratory in Hartford, Conn., **John H. Howard**, the new director of research and engineering, will pilot activities in Bridgeport, Conn., Burlington, N. J., and Long Island City, N. Y. Howard's previous connections include Burroughs Corp. (manager of engineering services), Engineering Research Associates, Inc. (director of development), Sperry Gyroscope Co. (project engineer), and MIT (research associate). He chairmanned the joint AIEE-ACM-IRE Computer Committee in 1953 and the Professional Group on Electronic Computers in 1953-54.

►A similar title, that of director of research and development, has been assigned **Morton B. Prince** by the National Semiconductor Div. of Hoffman Electronics Corp. Prince has been with Bell Telephone Laboratories and MIT's Research Laboratory of Electronics, and has lectured at Stevens Institute of Technology.

►**Dr. Robert B. Cory**, an authority on airborne computers, has joined the engineering staff of Trio Laboratories, Inc. Cory has taught physics at RPI, the University of Arizona, and Colorado A&M.

►**Dr. John A. F. Gerrand**, named director of geophysical research in the Central Research Div. of Texas Instruments, Inc., will supervise the work of TIC's subsidiary Geophysical Service, Inc., and its eight affiliated companies. Gerrand, who formerly held the same position with Houston Technical Laboratories, another TIC subsidiary, replaces **Dr. Hal F. Jones**, now chief engineer of HTL. His previous affiliations include Electro-Technical Laboratories, Northwest Seismic Surveys of Calgary, Can., and California Standard Co. of Canada.

►The new manager of the Quality Control Dept. of Airborne Instruments Laboratory, Inc., is **Oliver Simms Jr.**, formerly with the QC Dept. of Sperry-Rand Corp. He has lectured in his field at Hofstra College, Hempstead, N. Y.

►The appointment of **Clarence L. Johnson** to the new position of vice-president for research and development of Lockheed Aircraft Corp. has resulted in two changes in Lockheed's California Div., where he had been chief engineer. The changes, both promotions, are: **John B. Wassall**, formerly assistant chief engineer, to director of engineering, and **M. C. Haddon**, formerly chief project engineer, to chief engineer. Johnson, who will continue contacts with Lockheed's three aircraft and missile divisions as well as with certain experimental projects of the California Div., joined the company in 1933. He headed a hand-picked crew that secretly built the P-80, the first jet fighter to see combat, and supervised design of the F-104, the supersonic fighter unveiled just last April. Wassall left Beech Aircraft Co. in 1937 to join Lockheed's then-subsidiary Vega Airplane Co., which became a full part of Lockheed in 1944. Haddon joined Lockheed in 1940.

►When **Dr. Charles R. Burrows**, formerly director of Cornell University's School of Electrical Engineering, takes over this month as vice-president for engineering at Ford Instrument Co., one of the projects to be handed him consists of Ford's designs for the nation's first closed-cycle gas turbine nuclear reactors. An internationally-known scientist, Burrows has been associate chief scientist of General Electric's Advanced Electronics Center and a specialist in electronic research at Bell Telephone Laboratories. He has been president of the IRE and of the Joint Commission on Radio Meteorology of the Internation Council of Scientific Unions, and currently is vice-president of the International Scientific Radio Union.

►Forty-two years ago **Thomas J. Watson Sr.** became president of the Computing-Tabulating-Recording Co. and borrowed $40,000 to bring the rocking

firm to its feet. He put $25,000 of the money into an engineering laboratory and the rest into a salesman-training program, and came up from the floor with an industrial empire known as IBM. Last May, Watson, now 82, surrendered the post of chief executive of his company to his son, **Thomas Jr.,** who has been president since 1952. The change capped a meteoric rise by the younger Watson, who since the war has held the posts of assistant to the executive vice-president, vice-president, executive vice-president, and president. He will continue in the presidency, while his father will continue as chairman of the board.

►**T. P. Heuchling,** formerly with Ultrasonic Corp. and MIT's Servomechanisms Lab, has joined Feedback Controls, Inc., as chief engineer.

►**Morris F. Ketay,** president of Norden-Ketay Corp. and founder of the predecessor Ketay Mfg. Co., has retired to "a less active role". His successor is former Executive Vice-President **Perry R. Roehm,** who came to N-K in 1955 after serving as vice-president of Barden Corp. Ketay will continue as a consultant and as a member of the board.

►Century Electronics & Instruments, Inc., has named **Richard Gode** chief design and development engineer for its Switch Div. Gode has had experience in the petroleum engineering and geophysical departments of some of the major oil and utility companies, including Service Pipe Line Co. and Public Service Co. of Oklahoma.

►The Application Engineering Dept. of Minneapolis-Honeywell Regulator Co.'s Brown Instrument Div. recently gained 30 years' more experience. This is how long **Louis Gess,** the department's new staff consulting engineer, has been in the instrument engineering field.

►The Instrument Div., the fifth and last division in Fischer & Porter Co.'s divisional decentralization program, has been organized under **Donald J. Tricebock,** formerly assistant to the sales manager. Tricebock came to F&P in 1952 from RCA Victor, where he had been an electronic design engineer.

►All of The W. L. Maxson Corp.'s electronic research and development activities are now under the supervision of **Murray Simpson,** Maxson's new assistant vice-president. Simpson formerly was with Fairchild's Guided Missiles Div. and Raytheon Mfg. Corp.

►New appointments in the Instru-

WHAT'S NEW

ment Div. of The Perkin-Elmer Corp. are: **R. V. Harris** to assistant general manager; **John G. Atwood** to director of engineering, and **Henry F. Brockschmidt** to director of manufacturing. Harris came to P-E in 1949 as director of production after experience with the MIT Radiation Laboratory, General Electric, and Taylor Instrument Cos. Atwood, with P-E since 1948, most recently was technical assistant to the director of engineering. He previously had been with M. W. Kellogg Co. Brockschmidt, formerly with Barber-Colman Co., joined P-E in 1951 as assistant director of production and was assigned to foreign operation in 1955.

► **Wayne K. Hodder**, formerly with Hughes Aircraft Co., General Precision Laboratory, and MIT's Radiation Laboratory, joins Consolidated Electrodynamics Corp. as a senior development engineer specializing in airborne instrumentation systems.

► The Aeronautical Div. of Robertshaw-Fulton Controls Co. has named **Vernon H. Vogel** director of engineering, a new position. He will be expected to implement a project approach linking the developmental and production activities of the division.

► American Machine & Foundry Co.'s Mechanics Research Dept. of Chicago, which deals in such fields of engineering mechanics as heat-power, thermodynamics, automatic machine functions, instrumentation, applied electronics, etc., has a new director. He is **Dr. Severin Raynor**, most recently chief of the Engineering Div. of the University of Chicago's Chicago Midway Laboratories.

► **Robert R. Lent**, appointed West Coast coordinator for the Electronics & Instrumentation Div. in Baldwin-Lima-Hamilton Corp.'s guided missile program, comes to B-L-H from Reaction Motors, Inc.

► Electronic Engineering Co. has made a television star out of an electronic engineer. The engineer, **Dr. Martin Klein**, simplifies the insides of complex electronic devices for Saturday afternoon TV audiences on the company's program, "Wires and Pliers".

All Around the Business Loop

► *The Journal of Commerce* came out May 14 with a pretty heady statement about recruitment of high-level personnel by control-field companies bidding on military contracts. And to

MICROWAVE
AIRLIFT...

Transportable 800 lb. Magnesium antenna mast telescopes to 100 ft. Trained crew of 8 men can erect mast in less than an hour.

Microwave System capabilities include the transmission of voice communications (up to 72 two-way channels), radar data and radar control functions.

Transportable Packages Grow into Miles of Communications in 2 Hours

A microwave station that can be transported to a site by helicopter and then put into operation in as little as two hours has been developed by Motorola for the U.S. Air Force. The equipment was designed to satisfy Air Force requirements for high information handling capacity, transportability, and quick installation.

Positions open for Engineers and Physicists.

MOTOROLA

COMMUNICATIONS & ELECTRONICS DIVISION

National Defense Department

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illustrate its point, that there is "piracy of top-ranking scientists", the *Journal* told how **The Ford Motor Co.** went about setting up its new subsidiary, **Aeronutronic Systems, Inc.** If anything, the newspaper's selection was unique. It certainly was not relevant.

Before becoming a Ford subsidiary, Aeronutronics was known as **Systems Research Corp.** It had been going under the latter name for about five months, or ever since its chief executives left **Lockheed Aircraft Corp.'s Missile Systems Div.** to go into business for themselves in Van Nuys, Calif. (CtE, February, p. 24). Little has been heard of Systems Research since that time, but chances are the men who formed it consider their association with Ford to be quite a break. In any case, it's some stretch of the imagination to say a thing is pirated away when no one is left to grieve.

According to Ford's chairman, Ernest R. Breech, the new subsidiary's field will range "from guided missile systems to possible exploration of outer space". With a breadth as wide as this, it's no wonder that Ford wants to get Aeronutronics fully under way before it decides whether its work can be carried on in existing plants, or whether new facilities have to be built. This much, however, is certain, Aeronutronics' President Gerald J. Lynch says: "We expect to take a weapons system problem or other project and see it through from its very conception through test, and to its manufacture in the quantities required."

The subsidiary is operating on a $10-million Ford investment, and there's a good possibility it may get $4 million more for a research plant. Besides Lynch, who has been director of Ford's Office of Defense Products & Government Relations since 1954, other officers, all former Lockheed and Systems Research men, are Dr. Ernst M. Krause, vice-president for research and development; Dr. Montgomery H. Johnson, director of R&D, and Dr. Joseph V. Charyk, head of the Aerodynamics & Propulsion Div.

San Francisco and Los Angeles are being considered as sites for the new subsidiary, which expects to employ between 1,000 and 2,000 people by 1958.

► The prototype of **Stanford Research Institute's** Electronic Recording Machine, Accounting, that **The Bank of**

Information-gathering costs down 60% . . . test results available in 65% less time! That's the story at Marquardt Aircraft Company's "Jet Laboratory" in Van Nuys, California, since installation of a CEC Data-Processing System. Custom-designed for Marquardt's specific needs, the system helps their engineers evaluate a new ramjet "at a glance". . . helps checkmate troubles at the very outset of testing. It brings true automation to the reduction, listing, compensating, and computation of data, formerly accomplished entirely by manual means.

Dynamic and static testing . . . the function of the Marquardt System . . . is but one of the fields to which Consolidated's Systems Division can bring the *full, combined* benefits of automation and instrumentation. Whether you're interested in such engineering and development testing . . . or in process monitoring and control, chemical analysis, or data processing . . . let CEC's Systems Division look at your problem. The results will pay off for you for years to come.

less time, less cost for product development

Here's how Marquardt's CEC Data-Processing provides *more* data at *less* cost in *less* time . . .

. . . samples 100 channels in 0.25 second or scans an individual channel at any rate up to 1200 samples per second.

. . . automatically amplifies and digitizes temperature, pressure, and flow measurements.

. . . records digital information on magnetic tape for transfer to punched cards or to an electronic computer at whatever rate demanded.

. . . connects any data channel into any or all of three data-presentation modes: recording oscillographs, high-speed digital converter, or remote meters.

. . . generates a precise time base for recording along with data at instant of sampling.

. . . gathers and stores digital information by means of a tape-to-card converter (magnetic-memory drum and relay storage) for utilization by IBM punch.

For more facts on what CEC Systems Engineering can do for you, write for Bulletin CEC 1304-X24.

Systems Division

Chemical Analysis | Process Monitoring and Control | Dynamic and Static Testing

Consolidated Electrodynamics Corporation

formerly Consolidated Engineering Corporation

300 North Sierra Madre Villa, Pasadena, California—SALES AND SERVICE OFFICES IN: *Albuquerque, Atlanta, Boston, Buffalo, Chicago, Dallas, Detroit, New York, Pasadena, Philadelphia, San Francisco, Seattle, Washington, D.C.*

Electronic Instruments for Measurement and Control

America installed in San Jose, Calif., late last year (CtE, December '55, p. 18), has proved to be the forerunner of the biggest civilian order for industrial computers in history. The order represents a dream-come-true for President S. Clarke Beise, who in 1955 envisioned a battery of fast-working bank accountants, each one of them named ERMA. The new computers, to be built by **General Electric Co.'s Electronics Div.** in space leased by SRI at Menlo Park, Calif., will be somewhat different from the San Jose model. The greatest change: the use of transistors rather than vacuum tubes.

No word has been given out concerning the cost of the project, but it's known that it will be a major addition to GE's **Industrial Computer Section** program. Besides the contingent at Menlo Park, GE has put its Syracuse, N. Y., facilities, and its Palo Alto, Calif., laboratory to work on the bank's order and expects to start delivering components next year. Manned by eight operators and clerks on a two-shift basis, ERMA will perform the daily bookkeeping tasks for more than 55,000 commercial checking accounts.

► Military orders for development and delivery of precision engine control systems for advanced turbine-controlled aircraft and guided missiles have catapulted **Sperry Gyroscope Co.** into the field of supersonic flight. The orders, measured in "millions of dollars", call for a shock-positioner control system for a ram-jet missile and variable geometry controls for a new supersonic fighter engine. It's not at all improbable that Sperry's new **Sunnyvale (Calif.) Development Center** and its equally new **Microwave Electronics Div.** will have leading roles in the project.

The center's two 10,000-sq-ft buildings will specialize in radar, fire control, servomechanism, and missile systems under the direction of the main **Engineering Div.** and Dr. L. L. Wheeler, chief engineer at Lake Success, N. Y. Manager of the center is E. B. Hammond, formerly head of the **Airborne Weapon Systems' Engineering Dept.**

Under Manager Eugene J. Vanaglia, formerly director of the **Surface Armament Engineering Dept.**, more than 800 persons in the Microwave Div. will work on weapon support systems, Microline test equipment, antennas, and precision components.

► Under a permit issued by the AEC,

Now Available...

FIRST HF TRANSISTORS

now in production, meeting

Army Signal Corps Standards

A wide variety of military equipment, once impossible to transistorize due to frequency limitations of available transistors, is now being developed with Philco Surface Barrier Transistors.

PHILCO SBT

SURFACE BARRIER TRANSISTORS

(Type 2N128 and 2N129)

Meet MIL-T-12679A Military requirements

Check These Features

- **High frequency performance**
- **Extreme reliability**
- **Uniformity of characteristics**
- **Rigid quality control**
- **Minimum battery drain**
- **Low leakage currents**
- **Low operating voltage**
- **Absolute hermetic seal**
- **Meet MIL-T-12679A Military requirements**

Now available for large volume military and industrial applications . . . the high frequency Philco Surface Barrier Transistors that were developed for the Army Signal Corps to meet the stringent requirements of field use in military electronics equipment. Advanced precision techniques used in fabricating the Philco Surface Barrier Transistors make possible rigidly controlled automatic manufacture with its resultant uniformity, reliability and high volume production. These reliable transistors point the way to new fields in transistorization. Make these reliable high frequency Philco Surface Barrier Transistors part of your forward looking plans.

For complete technical information on these High Frequency transistors write Dept. CE-3, LANSDALE TUBE CO., Lansdale, Pa. A DIVISION OF PHILCO CORP.

PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

WHAT'S NEW

MIT and **ACF Industries, Inc.,** will build and operate an atomic research reactor on the Cambridge, Mass., campus. Patterned after the one in operation since 1953 at the Argonne National Laboratory, Lemont, Ill., the reactor will be used for medical therapy and atomic research development.

► A realignment in the **Engineering Div.** of **Vickers, Inc.,** has resulted in six new departments, one for research and development, one for administration, and four for the company's principal hydraulic product lines. Titles of the four latter departments are: **Industrial, Automation, and Marine; Ground Mobile; Airborne Products—Detroit;** and **Airborne Products—El Segundo, Calif.** Vickers' new **Administrative & Engineering Center** opened in Detroit just as the realignment was completed.

► "It may not be generally recognized, but since the end of World War II tremendous strides have been made in engineering in the European countries, particularly in France." With these words, Hector R. Skifter, president of **Airborne Instruments Laboratory, Inc.,** announced an agreement under which his company will manufacture and market electronic products developed by **The Compagnie Generale de Telegraphie Sans Fil** of Paris. Outgrowth of the agreement is a new American company, **Intercontinental Electronics Corp.,** financed by stock subscribed by **Airborne Instruments, Compagnie Generale, American Research & Development Corp.,** and **J. P. Morgan & Co., Inc.** Officers are Robert F. Schulz, president; Arnold Haase-Debosc, vice-president, and William H. Dobbins, treasurer and secretary.

► **Texas Instruments'** subsidiary, **Houston Technical Laboratories,** has taken over production and marketing of TIC's recording instruments. Two appointments accompany the transfer of operations from Dallas: Ralph T. Dosher Jr. to assistant chief engineer in charge of recorder development and design, and Orm F. Henning to assistant sales manager in charge of industrial instrument sales.

► Under a licensing agreement with **Control Specialists, Inc., Kelsey-Hayes Wheel Co.** will manufacture and sell automatic control systems and components designed by the Inglewood, Calif., concern.

► Plants at Pasadena and Van Nuys, Calif., comprise the new **Western Div.** of **Kearfott Co., Inc.** The Pasadena plant, headquarters for the division,

manufactures gyroscopes and aircraft control components, while the one at Van Nuys specializes in electronic and microwave components and control systems. Manager John R. Harkness steered the **Western Mfg. Div.** for the past six years.

▶ **Magnetic Amplifiers, Inc.,** has opened a new **West Coast Div.** at El Segundo, Calif.

Companies A-Building

▶ A $300,000 plant—the first designed expressly for the manufacture of magnetic recording tape for computers and color television—for **ORRadio Industries, Inc.,** of Opelika, Ala. All working areas of the 37,000-sq-ft facility will be dust-free, air-conditioned, and humidity-controlled. Scheduled for an October unveiling, the plant represents a 400-per-cent increase in ORRadio's production room.

▶ A million-dollar office building (more than 91,000 sq ft) in Hatboro, Pa., for **Fischer & Porter Co.** One feature will be a split-level cafeteria connecting the new building with present manufacturing facilities. F&P maintenance people will do most of the construction work.

▶ Office-warehouses in Detroit and Houston for **The Powers Regulator Co.** The $180,000 structure in Detroit (11,000 sq ft) will be occupied by **D. T. Randall & Co.,** agents. The one in Houston, costing $30,000 and providing 2,000 sq ft, will replace Powers' present quarters in that city.

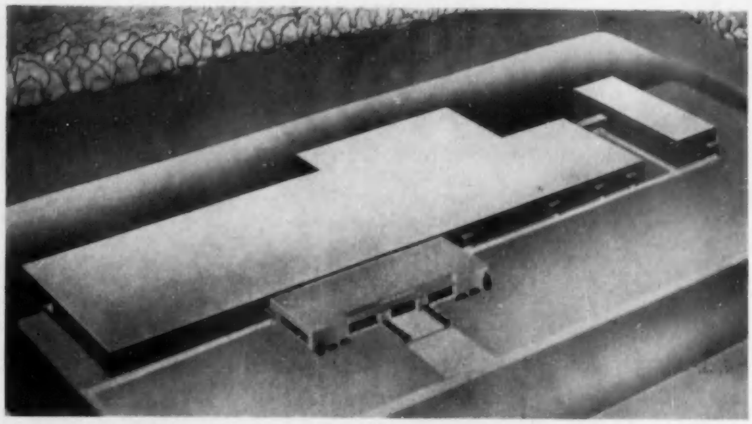
▶ A nine-building **Research & Development Center** in Los Angeles for **The Ramo-Wooldridge Corp.** The first 104,000-sq-ft unit of the $10 million project will be ready in November. To follow will be four other similar-sized units, each two stories high, a six-story executive and administration building, a one-story manufacturing facility, and a parking lot for 3,550 cars. All is set for completion by mid-1958.

▶ A research, development, manufacturing, and testing plant for the Atlas intercontinental ballistic missile ($40 million, a million sq ft) at Sorrento, Calif., for **Convair.** This is the second Convair facility devoted to missiles; the other, at Pomona, Calif., produces the Terrier surface-to-air weapon. About 6,600, under Chief Engineer Karel J. Bossart, are expected to be employed at Sorrento by 1958.

▶ Larger facilities in Florham, N. J., for **Automatic Switch Co.** Operations at Orange, N. J., where available space is just half of what the new

An office building in Hatboro for Fischer & Porter: 91,000 ft and a split-level cafeteria.

Powers Regulator Co. builds a home for its agents in Detroit: 11,000 ft. for $180,000.



Major contribution from the deep south: ORRadio magnetic tape winds out of Alabama.

Leeds & Northrup expands: all recording and controlling moves to North Wales, Pa.

plant promises to provide, will be moved to Florham Park by the end of the year.

▶ On May 11 the venerable Philadelphia instrument maker, **Leeds & Northrup Co.,** officially moved its complete industrial recording and controlling equipment line into a spanking new plant in suburban North Wales, Pa. The new facility is said to be one of the largest solely devoted to industrial instruments: it is located on a 129-acre tract, includes six acres of manufacturing floor space, and will house 1,300 people. L&N spent $4 million for the land and building alone, another $7 million for machinery and inventory. The company will continue its headquarters near the Wayne Junction station in Philadelphia, and will continue to make furnaces and laboratory equipment at the old location. However, many of the engineering people concerned with automatic control already have moved out to the country plant. The visiting control engineer should familiarize himself with the schedule of the local Reading Railroad trunk line, which will rattle him out to North Wales from Philadelphia in 40 minutes.

▶ Expansion in three states by **Lear, Inc.** The $3.6 million program involves a two-story wing addition to the **Aircraft Engineering Div.**'s hangar in Santa Monica, Calif., a 14,000-sq-ft addition to the **Lear-Romec Div.** in Elyria, Ohio, and a 170,000-sq-ft manufacturing plant for the **Grand Rapids (Mich.) Div.**

▶ A research and development center in Hawthorne, Calif., for **The National Cash Register Co.'s Electronics Div.** Activity in the 52,000 sq ft of space will be devoted entirely to advanced electronic computers and auxiliary equipment for business systems. A major feature of the computers will be their ability to adapt to cash registers, adding machines, and accounting machines.

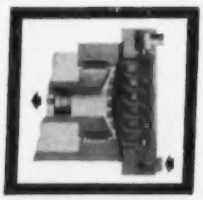
▶ A new transistor plant in Boston for **Minneapolis-Honeywell Regulator Co.** Though it is certain that the company's expanding **Transistor Div.** will be relocated in this city, no specific site has been chosen. Research work in transistors will continue at the Honeywell research center in Minneapolis.

Also for Honeywell: a fifth overseas plant, in Amiens, France, to pro-

CONTROLLED-VOLUME PUMPING with

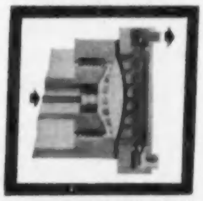
NO STUFFING BOX PROBLEMS!

The Pulsafeeder, in combining the good features of both piston and diaphragm pumps, provides an unusually dependable means of precision pumping. There is no stuffing box, hence the usual problems of maintenance and repacking associated with plunger-type metering pumps do not exist. The product being pumped is isolated from the pump's working parts by a hydraulically balanced diaphragm and is kept safe from contamination and leakage to atmosphere.



SUCTION STROKE

Positive displacement is achieved by a piston reciprocating within an accurately sized cylinder at an established stroke length, displacing an exact volume of hydraulic oil. By means of this oil, the piston moves the diaphragm alternately backward and forward. The displacement of this diaphragm travel takes in the liquid on the suction stroke of the piston and discharges a like amount of liquid on the discharge stroke of the piston.



DISCHARGE STROKE

WRITE FOR BULLETIN 440 *with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 701 Wilson Street, Le Roy, N. Y.*

Lapp

duce oil burner controls for France's domestic market. M-H is the first foreign company to open in Amiens, about an hour's drive from Paris.

▶ A factory-office building (76,000 sq ft) in Gardena, Calif., for **Sprague Engineering Corp.** Operations now carried on in five leased buildings will be centered in the new structure next fall.

▶ A rocket and missile plant and test center for **Thiokol Chemical Corp.** near Corinne, Utah. Between 400 and 500 employees of the Trenton, N. J., company will be assigned to the 10,000-acre site.

▶ An open-plan laboratory-type plant in Concord, Calif., for **Donner Scientific Co.** Donner, the first to reserve space in Concord's new "instrument park", anticipates a 500-person payroll there by 1957.

▶ New administrative and production buildings for **Richardson Scale Co.,** giving about 15,800 more sq ft of space to the Clifton, N. J., company.

▶ Other building activity: A 23,000-sq-ft addition to **Automatic Control Co.**'s facilities in St. Paul, Minn; a new plant (8,500 sq ft) for **American Research Corp.** in Farmington, Conn.; and consolidation at Waltham, Mass., of the Alexandria, Va., and Cambridge, Mass., facilities of **Feedback Controls, Inc.**

Several companies have been formed in recent weeks to manufacture control equipment or to service the field. Among them:

▶ **Brimberg Associates** of Washington, D. C., engineering and sales representative and consultant. Current clients: **Polarad Electronics Corp.** and **Sierra Electronic Corp.** President is Murray Brimberg, formerly with the Civil Aeronautics Administration and **Burlingame Associates.**

▶ **Computing Consultants, Inc.,** of Atlanta, Ga., computer and data-processor consultant, A. B. Simms is president and management consultant.

▶ Two acquisitions: **Lou-Bar Products** (control system components) by **Beckman Instruments, Inc.,** and **Airtronic Research, Inc.** (electronic devices and components) by **Harris-Seybold Co.,** Cleveland printing equipment manufacturer.

▶ And a merger: **Topp Industries, Inc.** (electronics manufacturer) and **Haller, Raymond and Brown, Inc.,** (electronics research).

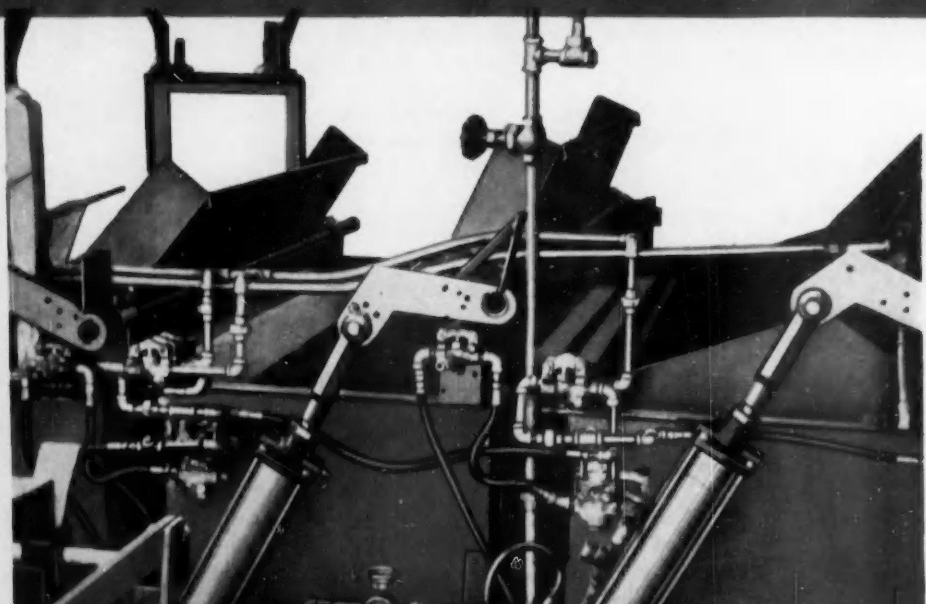
1

Hold and position work...with air Here, Schrader Air Products are used to hold burner grills and bend them into shape with a ton of force. Before air was adapted to the job, only 150 pieces were produced per hour. Now, with air, 620 pieces are produced in the same time.

AUTOMATE..

2

Move work...with air In this particular adaptation, plated parts are automatically washed three times. Air products lift the baskets, immerse them, lift again, and transfer them to the next bath. Operator simply presses button to start the sequence of interlocked cylinders and controls, all developed by Schrader.

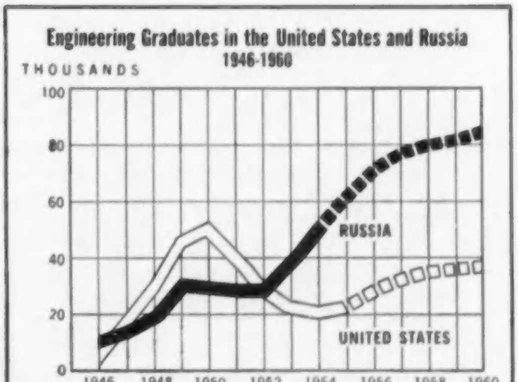


THE SHORTAGE OF SCIENTISTS AND ENGINEERS:

Are We Losing the Race with Russia?

THERE is new confidence in the Kremlin. One key reason is expressed in a recent boast of Communist Party Secretary Khrushchev: **"The capitalists always regard our people as being backward, but today we have more engineers and more supporting engineering technical personnel than any capitalist country."** He promised that this lead would be widened and that communism would be victorious without war.

This boast cannot be dismissed as communist propaganda. Admiral Lewis L. Strauss, chairman of the U. S. Atomic Energy Commission, has warned: **"In five years our lead in the training of scientists and engineers may be wiped out, and in ten years we could be hopelessly outstripped. Unless immediate steps are taken to correct it, a situation, already dangerous, within less than a decade could become disastrous."**



Source: Nicholas De Witt, Soviet Professional Manpower; U S Office of Education; McGraw-Hill Dept. of Economics

This second editorial in a series on the shortage of scientists and engineers is designed to explore as carefully as possible the facts and the implications of the new emphasis on technical training in the Soviet Union. It draws heavily from the authoritative book *Soviet Professional Manpower*, prepared for the National Academy of Sciences and the National Research Council by Nicholas DeWitt of the Russian Research Center of Harvard and released recently by the National Science Foundation.

Trend Is Against Us

If the Soviet Union already has a lead in technical manpower, it is not very great. Both the United States and Russia now have around a million scientists and engineers. About a third of the Russian engineers were trained on inferior pre-1935 standards. **It's the trend — shown in the chart — that is alarming.**

Over the last five years we have turned out only 142,000 engineers, compared to an estimated 216,000 in Russia. In 1955 our output was around 23,000 compared to their 63,000. Over the next five years our projected output is 153,000, against at least 400,000 in Russia. There will be an additional 150,000 or more in the satellites and Red China.

In Russia, 30% of the college students are in engineering, compared to 8% here. Another 30% or more take degrees in natural sciences. Moreover, unlike ourselves, the Russians are

ploughing back a large proportion of their science graduates into teaching, which implies a rapid buildup in the future.

Quality As Well As Quantity

It would be foolhardy to assume that these new Russian graduates are inferior to ours in the quality of their technical training. They start out with much more intensive mathematical and scientific preparation at the high school level. They study harder and longer in college, with more laboratory work and more practical training. Their courses and textbooks seem to be as thorough as ours. Even though the Russian graduates may be overspecialized, they get results.

These results have been striking. The Russians developed both A-bombs and H-bombs faster than we expected, and it's not certain that they had to rely much on espionage. They pushed ahead of us for a while in jet fighter design, and they showed up with a fleet of long-range bombers well ahead of schedule. They are crowding us on nuclear power, electronics and automation. There are grave fears that they have established a lead in the vital field of military rockets.

The goal of Soviet scientific manpower policy includes not only weapon supremacy but also leadership of the neutral and uncommitted areas of Asia, Africa and the Middle East. The Soviet leaders may be bluffing in their offers to export capital, but they are preparing to export Russian scientific and technical know-how in a big way.

How They Do It

The Russians are determined to win the race for scientific supremacy, and they do not count the cost. **They pay their scientists and engineers salaries that seem fantastic when compared with other Soviet incomes.**

Senior professors, research scientists and top engineers are a major segment of the Russian elite. Their incomes are frequently six to ten times the average industrial wage. (In the U. S. six to ten times the average industrial wage would be $25,000 to $40,000 a year.) Housing and other privileges are correspondingly lavish. While preaching equality, the Soviets use capitalistic incentives far more boldly than we do. Indeed, practicing engineers and scientists have been complaining about the exalted status of professors and top research people, and salary scales are now being adjusted to give greater emphasis to practical results.

The Russians are also generous in their aids to education. Tuition has just been made free at all levels. Undergraduates receive 200 to 500 rubles a month and graduate students 800 rubles (about equal to an industrial wage) to cover living expenses. The biggest stipends go to science and engineering students. College students are deferred from military service, and engineers and scientists often enjoy continued deferment even after graduation.

Finally, the Soviet leaders can channel engineers and scientists — and all other human and material resources — into any area they choose. And the areas the Soviet leaders choose are predominantly those that contribute to military or political objectives, rather than to a better life for consumers.

What's Our Answer?

We are certainly not going to adopt Soviet methods. We do not want scientific robots, but free men, able to understand and add to our democratic heritage. At the same time, our world leadership in technology — and perhaps even our survival as a nation — will be threatened if we allow ourselves to lag far behind Russia in the training of scientists and engineers. Ways to keep the United States in the race will be discussed in a later editorial in this series.

This is one of a series of editorials prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nationwide developments of particular concern to the business and professional community served by our industrial and technical publications.

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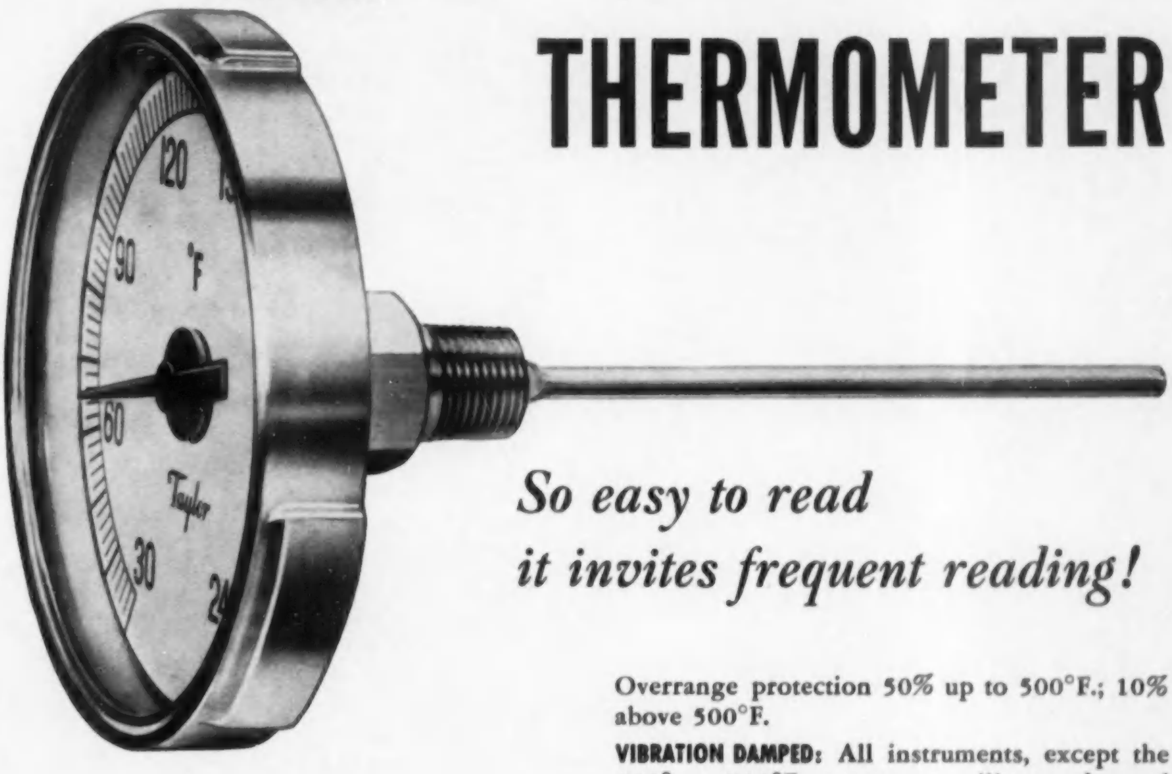
Donald C McGraw
PRESIDENT
McGRAW-HILL PUBLISHING COMPANY, INC.

Traditional Taylor accuracy in a low cost instrument

THE NEW BI-THERM* 5" DIAL THERMOMETER



So easy to read it invites frequent reading!

A SIMPLE, dependable and economical thermometer with many applications throughout industry. Wide variety of ranges from minus 40° to +750°F. Also available with three inch dial; stem lengths of 4, 6, 9, and 12 inches; separable wells of brass, steel, type 304 stainless steel or monel.

EASY TO READ: The large dials are highly readable because of black figures and graduations on an aluminum background.

RUGGED: All exposed metal parts are of arc welded, corrosion-resistant stainless steel. All instruments are waterproof. All mechanical connections are welded for greater reliability.

ACCURATE: These instruments are accurate within ±1% of range, over the entire range. Simple zero-setting features correct minor errors in readings which might result from severe mechanical shock. No ambient temperature effect. Overrange protection 50% up to 500°F.; 10% above 500°F.

VIBRATION DAMPED: All instruments, except the 200° to 750°F. range, are silicone damped against vibrations. Result is increased speed of response, minimum pointer vibration, and elimination of pointer chatter when the thermometer is handled.

ECONOMICAL: Costs only **$16** to **$26,** depending on dial size and length of stem. Ask your Taylor Field Engineer, or write for **Bulletin 98267.** Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada.

*Trade Mark

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IN HOME AND INDUSTRY

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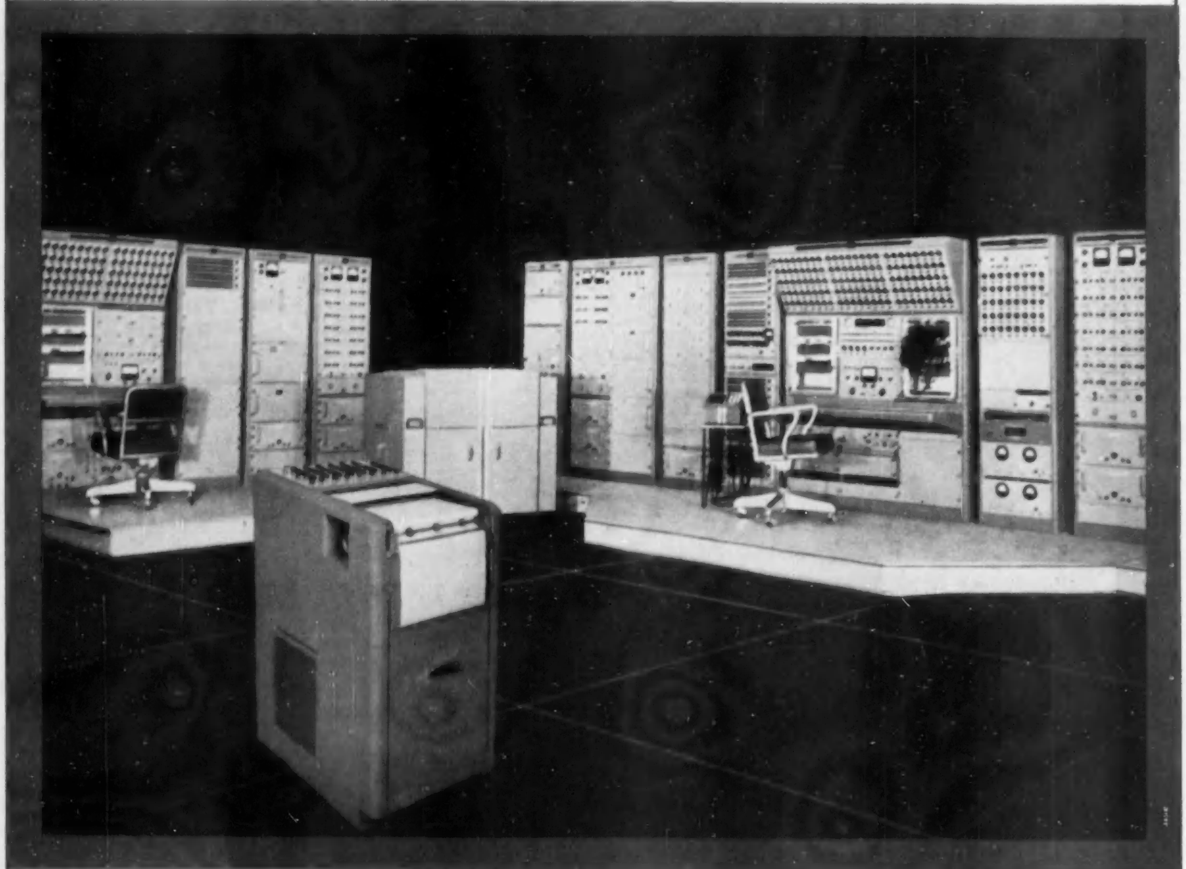

IN THE ENGINEERING PROBLEM

Of infinite help in easing the engineering load is Electronic Associates' PACE Computing Equipment. Each day, more and more major industries are relying on EAI Computing Systems for help in their engineering and development work, for they know they can trust its stability, reliability and operating convenience.

An example of this operating convenience is the push-button operation of the new Six-Channel Recorder, Model 1902A (pictured in the foreground of the computing system above). Push-button controls are provided in this recorder for individual selection of the recording scale factor of each channel — as well as a push-button speed selector which provides essentially instantaneous control of paper speed over the entire recording range. This Six-Channel Recorder provides the ultimate in recording accuracy, sensitivity, chart speed, widest band width, all at the lowest cost.

For detailed information on this equipment — on complete Computing Systems — and on the rental of time and equipment at the EAI Computation Center in Princeton, N. J., write Dept. CE-7, Electronic Associates, Inc., Long Branch, N. J.

ELECTRONIC ASSOCIATES *Incorporated*

EAI SETS THE P A C E

PRECISION ANALOG COMPUTING EQUIPMENT

LONG BRANCH, NEW JERSEY

Instrument Sales Treble in Seven Effusive Years

Few people besides H. C. Dickinson (see page 17, What's New) were able to predict the explosive growth of the measuring instruments industry during the years between 1947 and 1954. And now that the Census figures are in, there are many who still can't believe its tabulations.

Facts to silence challengers

But the cold facts on the value of instruments sold, carefully harvested by Census researchers and sifted by UNIVAC, are hard to challenge. Take the most modest growth—a mere doubling—which took place in that branch of the industry which the Census of Manufacturers' Standard Industrial Classification (SIC) labels "Electrical Measuring". Below are the figures for its three main sub-groups:

Classification	Sales in Thousands of Dollars 1947	1954
1—Electrical Integrating Instruments (chiefly watthour & demand meters)	63,650	73,090
2—Electrical Indicators & Recorders (panel, switchboard, ammeters, etc.)	38,998	84,184
3—Electrical Testing Equipment (oscillographs, engine test, etc.)	54,805	188,155
TOTALS	157,453	345,329

Control technology injects "adrenalin"

Except for a few mavericks, most instruments in the "Electrical" category showed a steady gain in this period: the mavericks —high-frequency scopes and recording units—increased eight times and four times, respectively. The reason seems clear. Electrical quantity measuring is functionally one of the oldest and most established branches of industrial instrumentation—its demand is hitched to the steady growth of power application. Nevertheless, the adrenalin of control technology was quite obvious in the more spectacular gains in equipment suited to controls systems test work. Confusing the neat picture, however, was the spectacular emergence of one semi-consumer item: the radio-tube tester.

Just change the pins for new process conditions.

Beckman "Pinboard" Data System Speeds Pilot Runs—Gets You On-Stream Faster!

A pilot plant isn't operated to make money; its purpose is to speed process development and plant design. With more of the right kind of information from a pilot plant, trial runs are completed faster, and the full-scale process is profitably on stream sooner.

The Beckman "111" Data System shortens pilot plant time because:

- exclusive pinboard programmer obsoletes all calibration and "knob-twiddling".
- all operations are digitally controlled.
- system is set-up with pinboard in a matter of seconds, eliminating time-consuming changes formerly required to meet new process conditions.
- results are presented in true physical units, such as pounds per square inch or degrees Fahrenheit, to a wide variety of read-out equipment.

To learn why leading companies are choosing the Beckman "111", write Beckman Instruments, Inc., Data and Control Systems Department, Fullerton, California. Ask for Data File D-1-46.

The Beckman Data System provides the link between plant instrumentation and tabulated data for use by your engineering and computer center.

Beckman® / "111" Data System

Our continued growth creates openings for additional creative engineers. Write for Career File #10.

The physical growth of the "Electrical Instruments" industry paralleled its sales: the number of plants grew from 154 in '47 to 302 in '54; employment was up 50% from 21,000 to 33,000; value added by manufacture rose 35%, from \$104 to \$248 million. Census found that most of this industry—about two-thirds of its employees—was still concentrated in the Northeast. But California is on the rise: a tenfold gain in plants, with employee growth from only 263 in '47 to 3,000 in '54.

A giant pea in the pod

Census figures for what SIC calls the "Scientific Instruments Industry" also show spectacular growth: total shipments increased 379% over 1947. However, as analysis of the table below will indicate, this surge is hardly indicative of progress in what a control engineer normally considers "scientific" instrumentation:

Classification	Sales in Thousands of Dollars 1947	1954
1—Aircraft Flight Instruments and Automatic Pilots	20,478	378,897
2—Other Aircraft, Nautical, and Navigational Instruments	—	136,935
3—Surveying & Drafting Instruments	19,658	17,998
4—Other Scientific Instruments & Lab Apparatus (excluding optical, elec. quantity meas., & indus. process)	*67,309	86,594
TOTALS	107,445	620,424

*This figure includes data for "other aircraft, nautical, and navigational instruments"—a separate category in the 1954 figures.

It is obvious that most of the growth in "scientific instruments" came from the meteoric, Korea-spurred emergence of automatic pilots—hardware that mainly reflects growth in computer-, servo-, and control-loop component manufacturing. In the conventional measuring tools for the scientist, growth was healthy, but far from trend-setting. However, the SIC breakdown here fails to include one product group that functionally —and commercially—bolsters the category: optical instrumentation. Now listed with the "Optical Instruments and Lenses Industry", the product measurers accounted for a \$20-million market in 1954. And with the trend to inplant use, the future prospect for spectrometers, colorimeters, refractometers, etc., seems loaded with growth. Going back to the table above, the \$620-million total figure for this industry is deceptive since, by Census admission, only 64% was shipped by plants in the SIC group —the rest being shipped by plants otherwise classified. This indicates the great amount of reselling done before an instrument reaches a user. Physical growth in the "Scientific

Analyzers "tucked away"

CBS

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in mass production

Whether your requirements are for a dozen or a million . . . for standard or special types . . . CBS is prepared to supply you with power transistors. And in a variety of metal cases designed to solve problems of mounting and heat dissipation.

The many advanced-engineering features of the CBS 2N156 (12-volt) and CBS 2N158 (28-volt) are ideally suited to high-power audio amplifiers, servo amplifiers, power converters, and low-speed switches. The CBS type 2N155 is especially designed for optimum performance in single-ended audio output stages of automobile radios.

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FEATURES OF CBS PNP JUNCTION POWER TRANSISTORS

1. High current gain at high current
2. High power-handling capabilities
3. High peak-back voltages
4. Stable, uniform characteristics (special selection unnecessary)
5. Low input impedance
6. Low saturation voltage
7. Low saturation current
8. Choice of hermetically sealed designs

Reliable products through Advanced-Engineering

CBS semiconductors

CBS-HYTRON
Semiconductor Operations, Lowell, Mass.
A DIVISION OF COLUMBIA BROADCASTING SYSTEM, INC.

Instruments Industry" was steady: there were 215 plants in '47, 367 in '54; employees rose from 18 to 43 thousand. Value added by manufacture zoomed from $75 to $34 million. The growth did not seem to favor any one area of the country.

"Mechanical" ranges afar

As far as the whole control market is concerned, SIC's most definitive grouping is in what it calls the "Mechanical Measuring Instrument Industry". Census figures in this area suggest what might be considered a "mean" or normal growth for the field:

Classification	Sales in Thousands of Dollars 1947	Sales in Thousands of Dollars 1954
1—Aircraft Engine Instruments	4,992	80,257
2—Integrating Meters (nonelectric)	63,262	106,174
3—Industrial Process Instruments (incl. ind., record., & control)	168,369	271,518
4—Motor Vehicle Instruments	39,495	76,401
5—Commercial Control Devices (for air-conditioning, refrigeration, heating, etc.)	100,640	259,970
6—Unspecified Mechanical Instruments	48,519	51,022
TOTALS	425,277	845,342

Sophisticated control devices

Once again, the greatest growth is identified with the aircraft industry. However, an unexpected near-doubling also took place in the more conservative industrial process control field—as indicated by sales of integrating meters and process instruments. The trend to continuous flow control in the latter group was obvious in gains in fluid and liquid level instrumentation, from $19 million in '47 to $40 million in '54. Another interesting increase was in equipment designed for human environmental control—what the table dubs "commercial control devices". While these products are traditionally nonindustrial in function, the growing sophistication of the systems they are being used in causes them to veer strongly toward the "process instruments" category—and thus quite often compete with process instruments in environment control systems. Physical growth of the "Mechanical Instruments Industry" was modest: while total sales went up 87% employment rose only 13% and the number of plants increased from 466 to 609. Value added, however, surged from $281 to $534 million. Although the New York area still leads in the number of plants (127), its growth has been negligible; California's, on the other hand, has doubled in this category.


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economical to install
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the great new flat multiple-tube instrument line harness
DEKORON
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Dekoron "M" Ribbon or "P" Ribbon makes instrument tubing costs plummet. That's because the chemical resistance of the plastic sheath even outlasts expensive alloy tubing . . . because you get all the advantages of bundle installation in a flat, easy-to-handle "ribbon" . . . because the perforated plastic "webs" between individual tubes enable tubes to be stripped back singly or in groups without tools and without destroying protective coating. So tube up with Dekoron "M" Ribbon or Dekoron "P" Ribbon —it's a "pipe" to install.
Dekoron "M" Ribbon consists of 10 individual copper or aluminum tubes with vinyl plastic coating; Dekoron "P" Ribbon is 10 polyethylene "P" tubes with vinyl sheath.
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Control ENGINEERING

JULY 1956

Needed: A New Industry Breakdown

Spring 1956 was the time of the Manufacturers' Census – and a time for a long, hard look at the growth of the control field market. The statistics we received from the Census Bureau in Washington were imposing and charged with signs of the vigor of our technology. See *Pulse*, page 61, for the tallies and *What's New*, page 16, for the story of how the data were processed.

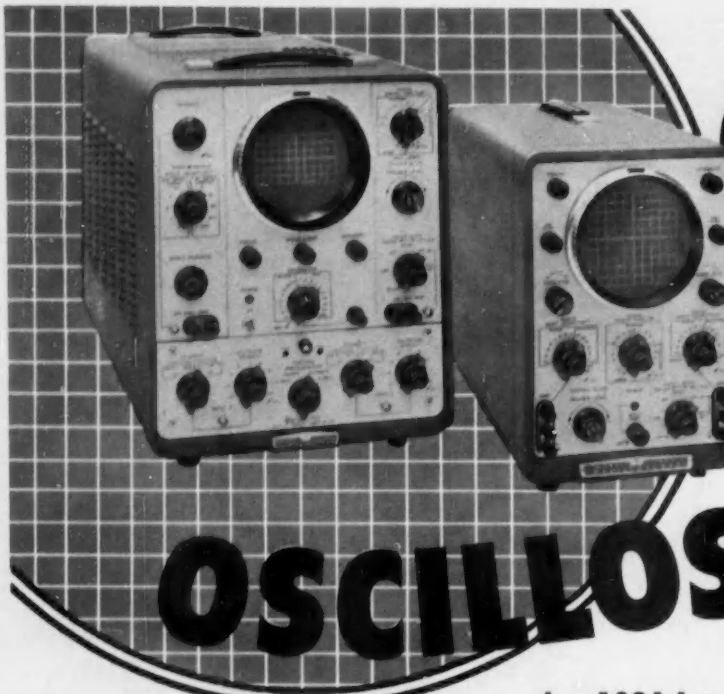
But when you take that long, hard look do you get a realistic picture of what has happened commercially to our field?

Looking for facts on progress in analytical instrumentation, what do you find? Half the product-quality measurers are tucked away with aircraft and surveying instruments. And the all-important optical subsystems are grouped with cameras, field glasses, and microscopes. Seek data on the volume of servo-type equipment and where must you turn? An undefined bulk is lost amid "Scientific Instruments" in figures on autopilot systems, and the rest is scattered through several industry groups. Probe for program controllers and you finally unearth them in a pile of wrist watches and alarm clocks. And in a Census category labeled "Mechanical Instruments" you find electronic process recorder-controllers – perhaps this one is not too wide of the mark.

The Census Bureau is really not to blame for the confusion. Its basis for grouping data, the Standard Industrial Classification (SIC), was developed in 1942 by careful study (and has served broad industry quite well since then). But meanwhile things have happened: in our case, a whole *field* took shape. SIC was not geared to correctly weight this field in 1947, nor in 1954. But it remained for the '54 data to dramatize the mismatch.

Recognition, definition, and proper classification of the control field are badly needed. At least one government agency, Nathan Golden's division in the Dept. of Commerce (CtE, June, p. 16) is aware of and is doing something about the need. Next month we will publish a new functional classification suggested by Golden's deputy from SAMA. Examine it carefully. Your critical feedback, or suggestion of a totally new approach, can spark the start. With your help there will be a new breakdown of the field – from the field – in time to assure more useful data from the Census scheduled for 1958.

THE EDITORS



Announces 2 all new OSCILLOSCOPES

BRIEF SPECIFICATIONS

-*hp*- 130A

Sweep Range: 1 μsec/cm to 15 sec/cm.
Calibration: 21 sweeps: 1-2-5-10 sequence, 1 μsec/cm to 5 sec/cm. 5% accuracy.
Triggering: Internal, line voltage or external 2 v or more. Pos. or neg. slope, +30 to —30 v trigger range.
Preset Trigger: Optimum setting for automatic stable triggering.
Input Amplifiers: (Similar Vert. and Horiz. Amps) Sensitivity 1 mv/cm to 50 v/cm; 14 ranges, continuous vernier. Pass band dc to 300 KC.
Amplitude Calibration: 1 KC square wave. 5% accuracy.
Price: $450.00.

-*hp*- 150A

Sweep Range: 0.02 μsec/cm to 15 sec/cm.
Calibration: 24 sweeps: 1-2-5-10 sequence, 0.1 μsec/cm to 5 sec/cm. 3% accuracy.
Triggering: Internal, line voltage or external 0.5 v or more. Pos. or neg. slope, +30 to —30 v trigger range.
Preset Trigger: Same as -*hp*- 130A.
Horizontal Amplifier: Magnification 5, 10, 50, 100 times. Vernier selects any 10 cm part of sweep. Pass band dc to over 500 KC. Sensitivity 200 mv/cm to 25 v/cm.
Vertical Amplifier: Pass band dc to 10 MC. Optimum transient response and rise time less than 0.035 μsec. Signal delay of 0.25 μsec permits leading edge of triggering signal to be viewed.
Amplitude Calibration: 18 calib. voltages, 2-5-10 sequence, 0.2 mv to 100 v peak-to-peak. Accuracy 3%. Approx. 1 KC square wave, rise and decay approx. 1.0 μsec.
Prices: -*hp*- 150A High Frequency Oscilloscope, $1,000.00.
-*hp*- 151A High Gain Amplifier, $100.00.
-*hp*- 152A Dual Channel Amplifier, $200.00.

Data subject to change without notice. Prices f.o.b. factory.

-*hp*- 130A Low Frequency Oscilloscope

High sensitivity, dc to 300 KC. Sweeps 1 μsec/cm to 15 sec/cm.

-*hp*- 150A High Frequency Oscilloscope

Dc to 10 MC. Plug-in preamplifiers. Sweeps 0.02 μsec/cm to 15 sec/cm.

As a result of a totally new design philosophy, -*hp*- 130A and 150A Oscilloscopes set revolutionary standards for oscilloscope usefulness, convenience and rugged dependability. The instruments' wide versatility is indicated in the specifications at left. Their greater convenience and reliability is inherent in such unique features as: Universal automatic triggering system wherein one preset adjustment provides optimum triggering for almost all conditions. Unitized circuits, easily isolated for testing. Etched circuits, mounted on translucent plastic for "see-through" serviceability. Complete accessibility of all circuits and tubes. Highest quality components. Ultra-conservative design, with circuits operating well below ratings. Concentric, color-coded controls, grouped by function and simplified. Direct sweep time selection—no mental gymnastics. A new low capacitance clip-on probe (for -*hp*- 150A) has 10 megohm impedance.

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Six Industrial Users Size Up Automatic Data Logging

CONTROL ENGINEERING STAFF REPORT

Automatic logsheet printing systems are relatively new to industry. Their justification is the subject of much current debate and study. The control engineer stands in the midst of the controversy, seeking hard facts that will enable him to make recommendations covering whether, when, and how to install automatic loggers in new and existing plants. Recently six potential and actual users of automatic loggers reported on their studies and practices at a symposium of the New Jersey Section of ISA. Papers and authors were:

1. **WHAT PRICE DATA, Dr. Robert L. Froemke, Standard Oil Co. (N. J.)**
2. **FACTORS INFLUENCING SELECTION OF PROCESS DATA HANDLING SYSTEMS, Albert H. Hix, Carbide & Carbon Chemicals Co.**
3. **THE CANADIAN PETROFINA INSTALLATION, Baron de Haulleville, Petrofina, Brussels.**
4. **A FACTUAL APPROACH TO DATA LOGGING, K. N. Thompson and George C. Johnson, Socony Mobil Oil Co.**
5. **DATA HANDLING IN THE PROCESS INDUSTRIES, M. W. Perkins and G. T. Cooper, M. W. Kellogg Co.**
6. **DATA REDUCTION APPLIED TO THE CHEMICAL INDUSTRY, E. B. Hall, E. I. du Pont de Nemours & Co.**

To aid other users and potential users, we have pinpointed the four main areas of these reports and the discussion they excited. But first a look at management's point of view.

Management's Viewpoint

"At mid-century we are forced to restudy the problem of data handling in business, since it embraces two of the central elements of control—measurement and communication. The problem has grown enormously in magnitude, exactly paralleling the growth of our modern industrial corporations. Simultaneously, the technology of instrumentation has created automatic data-logging installations for process units. However, this latter activity covers only a part of the total data problem that extends beyond production to include raw material procurement, product distribution, and financial control as well. . . . Consider the elements of administrative control that are quite similar to the elements of industrial process control. Essentially, the performance of the business must be measured and communicated back to the proper level of management for appropriate action if any control action is necessary. So the key elements are *measurement* and *communication.*

"So much for management's interest in electronic data-processing systems. In summary, it amounts to an *expectation* that these systems may be able to cope with the difficulties inherent in performing the measurement and communication functions of control in large organizations." *R. L. Froemke.*

WHAT AUTOMATIC LOGGERS DO

The speakers' plants consider data logging for several purposes:

- ▶ control of product quality and quantity to within specified limits through recording of process operating variables
- ▶ cost and yield accounting
- ▶ preparation of operating and managerial reports
- ▶ engineering analyses

REPORT I, on Recording

"In one refinery an automatic data logger has been installed which converts into a digital form measurements of flow, temperature, and pressure. The digital representations of the variables are recorded by two special electric typewriters with extra-large carriages and with punched paper tape attachments.

"The logger continuously monitors 88 variables and records this information either as a demand readout or at a predetermined interval which is continuously adjustable from 5 min to an hour. Of the 88 input measurements to the logger, 28 are pneumatic signals which are measurements of flow variables, 10 are pneumatic signals which are measurements of pressure variables, and 50 are thermocouple voltage signals which represent temperature variables. Except for some integration to replace chart planimetering, there is no computation." *R. L. Froemke* (above). [This system has a reported 99 per cent in-service record. It is expected to pay in manpower savings and increased data-taking reliability.]

REPORT II, on Centralized Control

"In the general design of a centralized control system, the intent was not to substitute the information system for normal operating techniques. The substitution of recorders by indicators was done conservatively. Only after considerable study of the importance of each controlled variable was it decided that indicating controllers were to be used for a majority of the points, since scanning and a temperature trend recorder are available.

"The data-logging system includes a console containing a process variable integrator, a conventional temperature indicator, a trend recorder, a patch panel, and three teletype machines. The console is located centrally in the control room and meets Class I, Div. II area requirements.

"The information system:

- ▶ **Logs** 259 selected process variables: flow, pressure, temperature, level, and hydrogen- and oxygen-analysis once an hour.
- ▶ **Scans** and alarms 70 process variables.
- ▶ **Computes** material and yield balances.

"Process variables are **logged** as instantaneous values, except flows, which are integrated; those flow values used in yield calculations are temperature- and pressure-compensated.

"The **scanning** system will automatically check the selected process variables against alarm point settings at the rate of five per sec. During the logging cycle, the scanning speed is slowed down to the logging speed. When the scanned variable is above or below the alarm setting, the audible alarm is sounded. If the variable is off-normal during the normal logging cycle, the variable will print in red on a normal logging typewriter. If off-normal during the scanning cycle, it will print red on an off-normal typewriter.

"Once per hour, the total input and output flows for each unit are compared and **computations** made for unit material balances and for the percentage of product yield. If the comparisons are off more than a pre-set percentage, a red symbol will be printed in the column provided on the log sheet, and if the comparisons are within the set limits, a black symbol is printed. The allowable percentage may be varied manually between zero and ten per cent." *G. C. Johnson* (left) & *K. N. Thompson.*

REASONS FOR AUTOMATIC LOGGING

1. Elimination of human error and bias

"No matter how well we have selected and trained our operator, there is still the possibility of error in manual logging of data from analog instruments." *E. B. Hall.*

". . . it is understandable that, *nolens volens*, some biased figures may be inserted between 'innocent' ones." *Baron de Haulleville*

2. Instantaneous cut

". . . the jotting of numbers takes considerable time. Therefore, [with manual logging] the operator does not get an instantaneous cut of a set of variables. With an elongated [manual] one, the variables at the end of the reading do not necessarily correlate with those written down first." *Baron de Haulleville.*

3. "A periodic and permanent log of the operating variables is obtained even during an emergency, which might otherwise divert the operator from his logging duties for extended periods." *E. B. Hall.*

4. Automatic loggers can "record data in forms directly usable in business machines, such as on punched cards, magnetic tapes, etc." *E. B. Hall.*

5. Automatic flow integration

"Instead of painfully and clumsily integrating, on nonlinear paper . . . it is evidently more accurate and less time-consuming to use a device that arithmetically adds data." *Baron de Haulleville.*

6. Manpower reduction

Because in continuous processing plants operating crews are already reduced to the minimum adequate for handling severe emergencies, there is little likelihood of control-room labor savings from the use of automatic loggers. "On the other hand, there is an appreciable amount of *clerical* labor involved in the preparation, handling, and filing of charts. We expect the clerical record handling time with an automatic logger to be considerably less." *E. B. Hall.*

7. One-time savings

Given automatic-logging equipment with proven performance and reliability, "a control room 50 per cent, or less, of its present size is indicated. But we are not yet willing to design for the maximum possible [initial] cost reduction advantage of data-reduction systems". *E. B. Hall.*

PREPARING FOR AN AUTOMATIC LOGGER

All of the study and experience reported show the necessity for team planning by many departments. The work, spearheaded by the instrument department people, cuts across organizational lines. This is not a new lesson, but a significant one for successful planning. *A. H. Hix* (right), reported these participating groups:

- Procedures Department (including accounting)
- Operating Department
- Engineering Department
- Instrumentation Engineering Department

He recommended the securing of this minimum information:

1. Detailed description of existing use of each measuring point in the system (information provided by Operating and Procedures departments).
2. Type and location of measuring elements and transducers (information provided by Instrumentation Engineering Department).
3. List of required logger functions (information provided by all four groups).
4. Detailed data-handling system specifications. This must include a specific logger function for each logged point (information provided by Instrumentation Engineering Department).
5. Quotation comparisons from data-handling-equipment manufacturers (information provided by Instrumentation Engineering Department):
6. Total installed cost of selected system (information provided by Engineering Department and Instrumentation Engineering Department).
7. A write-up of advantages to be gained in employing the data-handling system to justify purchase and installation (prepared by Procedures Department, Engineering Department, and Instrumentation Engineering Department).

The work will consume a great deal of engineering time. *Johnson* and *Thompson* suggested quadrupling the most pessimistic estimate of time. Consulting engineers, engineering contractors, and vendors can lighten the load, but the prospective purchaser still must prescribe his requirements.

Planned availability of qualified maintenance personnel is a prime requirement. Existing instrument maintenance personnel can master data-logging equipment if given thorough instruction at the manufacturer's plant or if they attend special training meetings set up by their instrument department. Socony Mobil assigned an engineer to relay information from the manufacturer to the refinery in which the logger was to be installed.

PROSPECTS FOR AUTOMATIC LOGGING

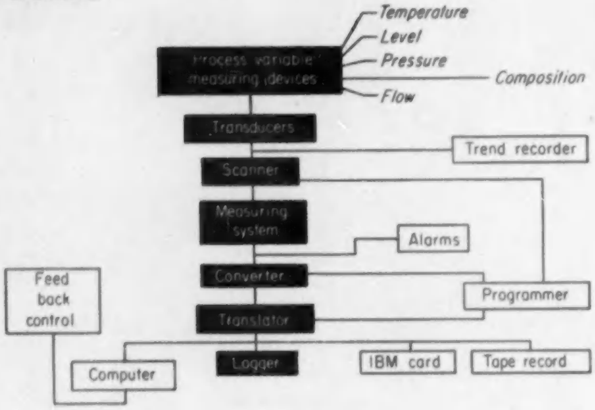


Fig. 1. Black blocks show automatic logger essentials. The items and functions added in white show the transition from a basic automatic logger to complete digital logging and control.

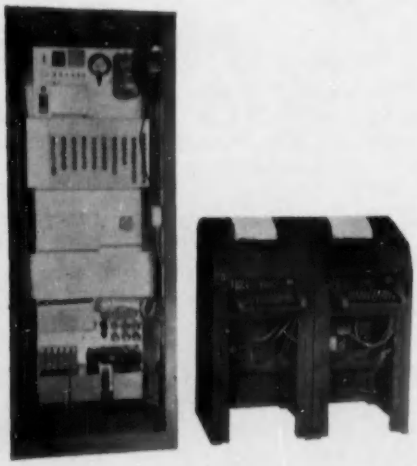
"In addition to the essentials [shown by dark blocks in Figure 1], data-reduction systems may contain devices . . . to add flexibility to the facilities. A few of the items that might be added are shown [by the white blocks]. Included are alarms, special programming, and additional outlets for the final digital data. The data may be punched on IBM cards, recorded on tape, or fed to a computer [which in turn might develop feedback signals to control the process]." *E. B. Hall* (above).

The technology and equipment are available for the calculation of operating, cost, and yield data. Agreement on the probability and desirability of calculating them is general, but the radius of centralized logging, computing, and control still fluctuates over an undetermined area. One group believes that it is practicable to centralize the control of simple and compact plants, but not of large and complex plants. Still another thinks that automatic coordinated control of widely scattered plants, all making the same type of product, is within the forseeable future. A central computer might receive telemetered measurements from each plant, analyze the measurements, and calculate adjustment of production rates necessary at each plant to achieve optimum overall cost. This is done today, by the way, in some electric power generation and distribution systems.

As most of the speakers and discussers reported on their first installation (actual or planned), there was little consideration of the second one. Today's intangible justifications cannot be put down in black and red until more users do plan their "second" installations upon a foundation of performance and economics laid by their first.

Copies of the complete proceedings are available from A. Adamson, M. W. Kellogg Co., 711 Third Ave., New York, N. Y.

For a complete rundown of logging means, see Control Engineering, February '56, page 67.



The first known digital recording system came into being in 1938 after four years of development initiated by T. G. LeClair of the Commonwealth Edison Co. (Chicago). It used a mechanical analog-to-digital converter that soon gave way to the electromechanical system shown.

Before the evolution of this digital recorder, individual circular-chart recorders were connected to each feeder line in unattended substations. Every day a chart collector drove to all substations and delivered his accumulated charts to a systems planning group for conversion of the chart records to numbers. Replacing this practice, the digital system records the amperage of each of sixteen feeder lines per station and the totals of groups of four lines. A rack, left, located in each unattended substation, transmits data in teletype code over telephone lines, tone channels, or microwave to printers, right, gathered in a control center.

NEW CONTROL COMPONENTS:

Nonlinear Ceramic Dielectrics

The ceramic dielectrics have been put to many uses in the control field, chiefly as transducers that make use of their piezoelectric properties. They have still another, far less exploited characteristic. They are nonlinear in the same way as are ferromagnetic materials: they display a hysteresis loop. Because of this analogy they are called ferroelectrics.

Nonlinear dielectrics can amplify electrical signals somewhat as magnetic amplifiers. Such dielectric amplifiers have several inherent potential advantages over magnetic amplifiers for voltage and moderate power amplifier applications. They are small and light-weight, have very low power consumption because they are voltage- rather than current-operated, and have a higher frequency response because of the faster switching of electric dipoles.

The dielectric amplifier compares favorably with the transistor, too. Being essentially a variable capacitor, it will have the life of a good-quality capacitor. And like the transistor, it has no filament and avoids this power loss. It is far simpler to make than the transistor.

It has two basic disadvantages, however: it requires a radio-frequency power source (it is basically a modulator—a much-used control technique itself) and operates only in a narrow temperature range.

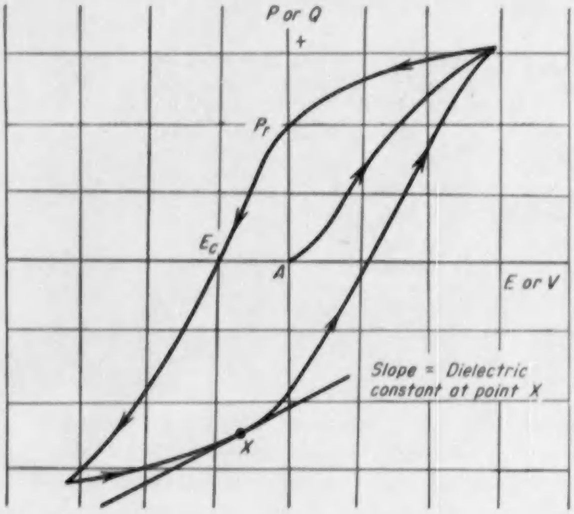
The ceramic dielectric's hysteresis loop also makes possible the ferroelectric memory. The saturated dielectric can store a binary-coded signal in much the same way as do magnetic cores. This use of ferroelectrics is still fairly well confined to the laboratory for the lack of large-enough high-quality crystals out of which to manufacture the multi-address matrices needed for computers. They shall some day make practical computer memories the size of a postage stamp.

NORMAN RUDNICK and GLENN HOWATT, Glenco Corp.

Surely, the electronic revolution of the past decade was spurred by the pressure of military needs. But it was nourished by a series of timely discoveries and inventions. An important example was the versatile ceramic, barium titanate, whose remarkable properties gave birth to a thriving new industry.

In some forms barium titanate has a dielectric constant as high as 8,000 to 10,000 as compared with 5 to 10 for conventional dielectrics such as mica, paper, glass, or some other ceramics. In practical terms, this radically reduced the size of capacitors and came at a time when miniaturization of electrical components was demanded by the increasing weight and space limitations in aircraft electronic

THE FERROELECTRIC HYSTERESIS LOOP FIG. 1



equipment. It has helped relieve the already overburdened foot soldier of much of the mass of his communications gear, has provided miniature hearing aids and radios, and has helped to restrain the enormity of such large systems as computers.

It was found also that barium titanate could be rendered piezoelectric, that is, it could transform mechanical energy into electrical energy and vice versa. This led to a multitude of applications in underwater sound transducers, phonograph pickups, microphones and loudspeakers, accelerometers, ultrasonic devices, medical instruments, and many others.

Nonlinearity, related to the ferroelectric behavior of barium titanate, is the least exploited characteristic of this remarkable ceramic. It is also the characteristic of special interest in the field of control engineering.

NONLINEARITY AND FERROELECTRICITY

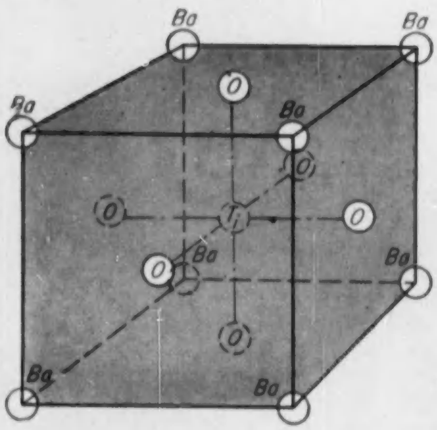
In the capacitor equation, $Q=CV$, Q is the charge stored, C the capacitance, and V the voltage applied. In a conventional capacitor, mica for example, a graph of Q versus V is a straight line, that is, linear, with a slope C proportional to the dielectric constant. In a barium titanate capacitor a varying voltage produces a hysteresis loop like that shown in Figure 1. The loop is exaggerated to show details. Here the plot of Q versus V (or polarization versus electric field) is curved or nonlinear. Since the slope is continually changing, the instantaneous capacitance is dependent on the applied voltage.

By analogy with the ferromagnetic hysteresis loop, which is similar in form to Figure 1 when the magnetic induction *B* is plotted against the magnetic field *H*, this dielectric hysteresis loop is called ferroelectric. Although barium titanate is not the only ferroelectric, it is the most widely used.

Because the capacitance of a nonlinear capacitor can be varied by changing the applied voltage, many applications are suggested, such as dielectric amplifiers, voltage-tuned filters or tank circuits, modulators, and sweep tuners.

Note that when an applied voltage is removed, the titanate capacitor does not return to a condition of zero charge, or zero polarization, but retains a remanent charge, Q, related to the remanent polarization *P*. This charge is positive or negative depending upon the polarity of the previously applied voltage. Thus the capacitor remembers electrically and is therefore of potential importance as a storage device for computers or control systems (see Fowler,

THE $BaTiO_3$ UNIT CELL



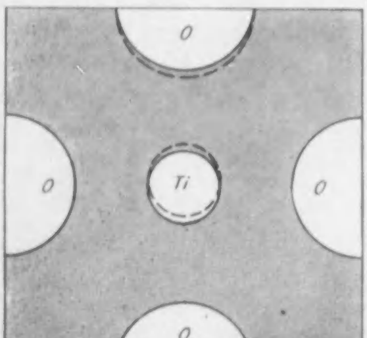


FIG. 2 (left). Unit cell of the $BaTiO_3$ crystal. Within a single pure unstrained crystal, these unit cells continue in all directions in a symmetrical arrangement. Only the Ti atoms are not shared by the adjoining cells.

FIG. 3 (right). Cross-section through unit cell shows how Ti displaces toward one of the O's. These displacements align throughout a single crystal, causing each crystal to have a spontaneous polarization. The crystal also elongates slightly in direction of displacement.

Basic Digital Series No. 8, CONTROL ENGINEERING, May 1956).

The memory function requires a broad, square hysteresis loop with vertical sides and flat top and bottom for best operation, while the other applications demand a narrow loop. Thus barium titanate is only the parent of a family of dielectrics whose characteristics are adjusted to serve different purposes.

THE HYSTERESIS LOOP AND BARIUM TITANATE

Barium titanate can be produced as a single crystal or as a polycrystalline ceramic. For some purposes the single crystal is superior to the ceramic, but for most, the ceramic has telling advantages. It is easily produced commercially, is very economical to use, can be fabricated in almost any shape or size, and its composition can readily be varied to achieve special properties. The single crystal is difficult and expensive to grow and is not adaptable to easy adjustment of composition. It is a laboratory item.

The ceramic is actually a conglomerate of many tiny crystals joined together in diverse ways and embedded in a glassy matrix. The result is a confused arrangement, which can be considered only statistically. In overall behavior, however, the ceramic resembles the single crystal sufficiently so that it is convenient to describe the ceramic properties in terms of the simpler structure of the crystal.

The ceramic differs from the single crystal in that the initial polarization is statistically zero, but resembles the crystal in that, once polarized, it follows a similar hysteresis loop forever.

The hysteresis loops, however, are different in that the ceramic loop has rounder knees, lower remanent charge, more sloping sides, and not quite so flat a top as the single-crystal loop. This is because dipole switching in the single crystal is relatively easy and uncomplicated, and polarization, in the form of chains of individual dipoles similarly directed, proceeds from unit cell to unit cell through the thickness of the crystal.

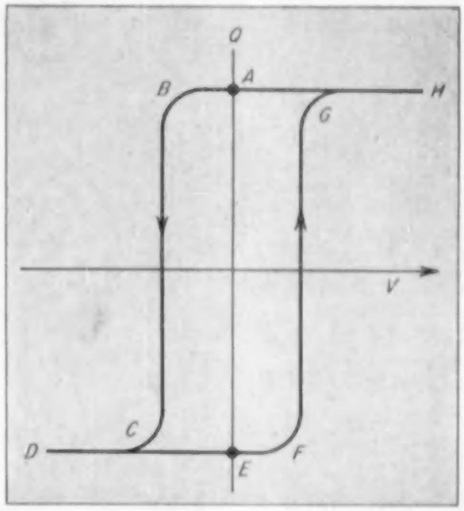
In the ceramic, not all the unit cells have faces so aligned that dipoles can be established parallel to the artificially induced polarization axis. Some can only strain in the direction of the sensed force and relax back when the force is no longer present.

Because the reorientation of the spontaneous dipole of a unit cell requires that the cell change its physical shape, this reorientation also demands a certain elastic freedom to deform. But this freedom may not exist due to the constraint of the matrix environment. The best the individual dipoles can do then is to attempt to follow the field as closely as their frequently awkward circumstances permit.

Because some of the dipoles require more force than others to switch their orientation, and because some do not switch at all but merely strain toward one direction or another, there is no sharp demarca-

THE UNIT CELL LOOP

FIG. 4



THE EFFECT OF VARIABLES ON $BaTiO_3$ HYSTERESIS LOOP

FIG. 5. TEMPERATURE

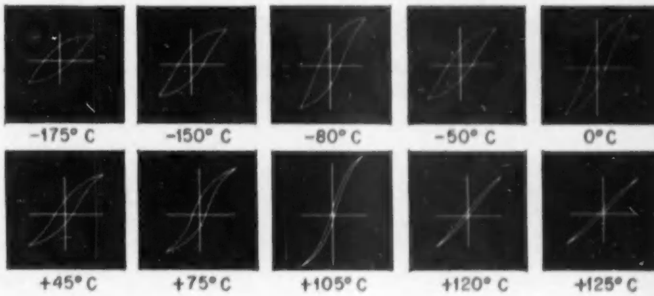
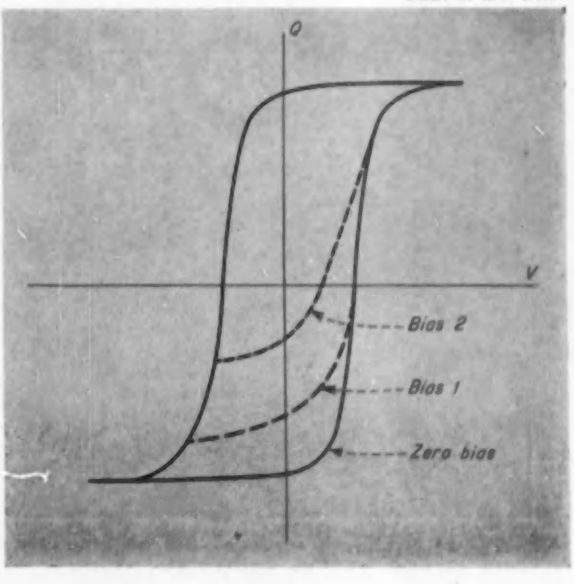


FIG. 6. DC BIAS



tion in the hysteresis loop indicating that the dipoles have suddenly switched. The "knee" is rounded. Also, because a slightly greater voltage may switch some dipoles too constrained to be switched at lower voltages or may further strain some incompletely aligned dipoles, the top of the hysteresis loop does not reach true saturation or flatness, but retains a definite slope.

When the voltage is removed, there is a greater relaxation in the ceramic than in the single crystal because the many strains introduced in the ceramic by distorting tiny crystals against an obstructing environment act to restore these crystals to a more unstrained state.

VARIATION OF NONLINEARITY

Nonlinearity varies with temperature, electric field, and time or frequency. Above its Curie point, 120 deg C, barium titanate loses its ferroelectric properties, and below the Curie point, in the ferroelectric region, the hysteresis loops are broad and pronounced. At the Curie point they narrow and above the Curie point they collapse. The charge-versus-voltage curve remains nonlinear somewhat above the Curie point, the degree of nonlinearity increasing with proximity to that point. Figure 5 shows the variation of the hysteresis loops with temperature.

If a dc field is applied to the nonlinear ceramic simultaneously with the ac field that traces out the hysteresis loop, the loop is distorted (Figure 6).

Since the dipoles require a finite time to switch, it might be expected that at higher frequencies the hysteresis loop would be suppressed. While it is difficult to study hysteresis loops at high frequencies, it has been found that the dielectric constant falls off rapidly somewhere above 100 mc., which presumably is an indication that the dipoles can no longer follow the rapidly changing voltage.

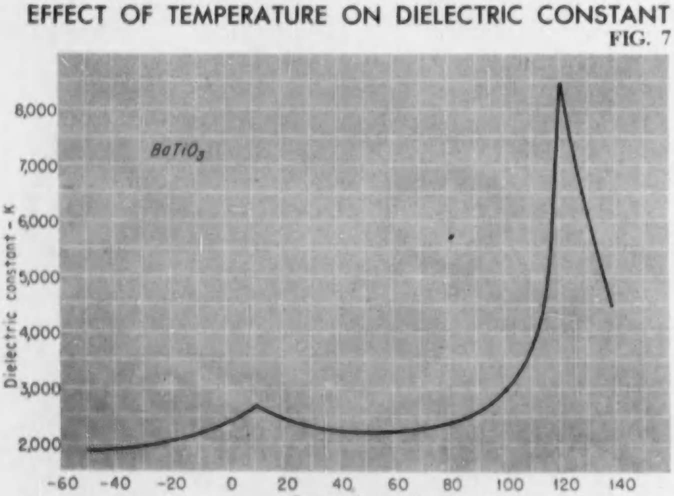
Another effect, that of dielectric heating, is of importance with respect to frequency. The area under the hysteresis loop represents heat loss per cycle. At higher frequencies there are more cycles per second, hence more heat generated per second. If this heat is more than the capacitor can dissipate to its surrounding, the temperature will rise to the Curie point, where the hysteresis loop collapses and the generation of heat subsides.

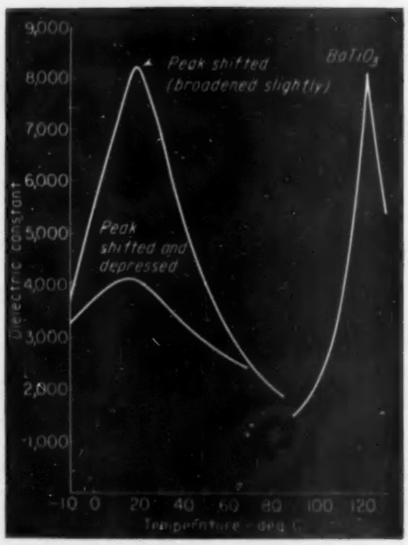
In practice nonlinearity is employed in two general ways and the effect of the above influences may be different, depending on the type of application.

First there is the change in small-signal capacitance with dc field. In this case the dc bias establishes a quiescent operating point on the major hysteresis loop while the weak ac signal performs a minor excursion about this point, sensing the slope of the loop in that region. As the bias is increased, the operating point approaches the flat top of the loop, the decreasing slope constituting less capacitance.

The second case is more related to Figure 6. Here, typically, a large amplitude ac carrier voltage continually traverses the major hysteresis loop and senses a value of capacitance which is an integrated average of the slopes over the entire loop. This may also be considered in terms of the flow of charge produced by the peak-to-peak change in ac voltage, which is a measure of the average capacitance. In the unbiased, undistorted hysteresis loop this charge is the difference between the positive and negative peaks, which, because of symmetry, is twice the positive peak. With bias, one half of the loop is

EFFECT OF TEMPERATURE ON DIELECTRIC CONSTANT
FIG. 7





EFFECT OF IMPURITIES FIG. 8

3 COMMERCIALLY AVAILABLE CERAMICS

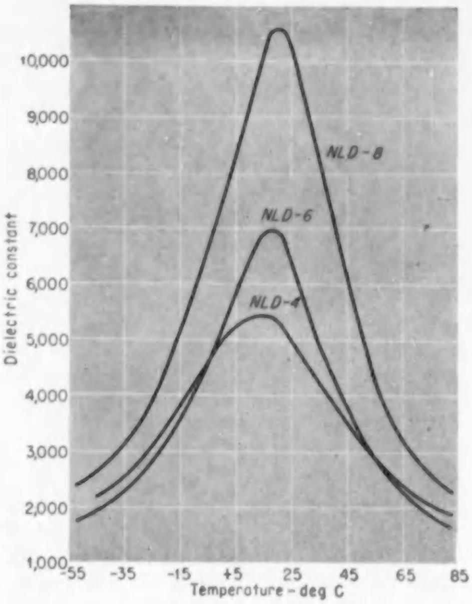


FIG. 9. Their temperature characteristics.

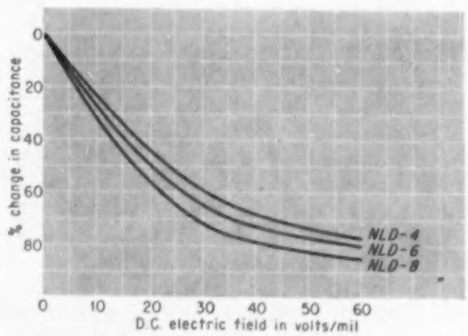


FIG. 10. Their capacitance variance.

shortened so that the peak-to-peak charge is decreased; hence, the effect is a decrease in average capacitance with increase in dc bias. The result is similar to that of the first instance, but the mechanism is somewhat different. Where large ac signals must be used, the heating effect of high frequencies is more severe. Also the effect of dc bias on the large-signal capacitance cannot be expected to be identical to its effect on a small-signal capacitance.

OPERATION ABOVE THE CURIE POINT

For a number of reasons it is frequently convenient to use a nonlinear ceramic capacitor just above its Curie point. If the small signal change in capacitance is expressed as a nonlinearity coefficient with units of per cent change in capacitance per volt of applied dc potential per mil of dielectric, it is found that this coefficient is greatest near the Curie point.

Also, a narrow hysteresis loop is of advantage. If the loop is wide, the capacitance corresponding to a given dc bias is two-valued, depending on whether the upper or lower portion of the loop is being used. Thus, if a varying bias is applied, the response will not be reversible, resulting in severe distortion. If a narrow loop, as occurs just above the Curie point, is used, the upper and lower portions of the loop almost coincide and distortion is minimized. In addition, a narrow loop is an indication of less dielectric heating, so that higher frequencies may be employed.

Unfortunately, the Curie point of barium titanate is at 120 deg C, an awkward temperature for most purposes and a temperature at which its conductivity is seriously increased. As can be seen from Figure 7, the capacitance-temperature curve is sharply peaked at this temperature, so that capacitance variation with small changes in temperature would be much greater than variation with electric field.

For these reasons additions are made to barium titanate to lower the Curie point and to broaden the peak, as illustrated in Figure 8. Figure 9 presents three nonlinear ceramic compositions produced by the Glenco Corp. Figure 10 shows the variation of small-signal capacitance with dc bias for these three materials. It can be seen that decreasing the temperature dependence by flattening the peak in the capacitance-temperature curve is done at a sacrifice of nonlinearity. But the Curie points are now slightly below room temperature so that these capacitors are better for normal use.

CONTROL APPLICATIONS

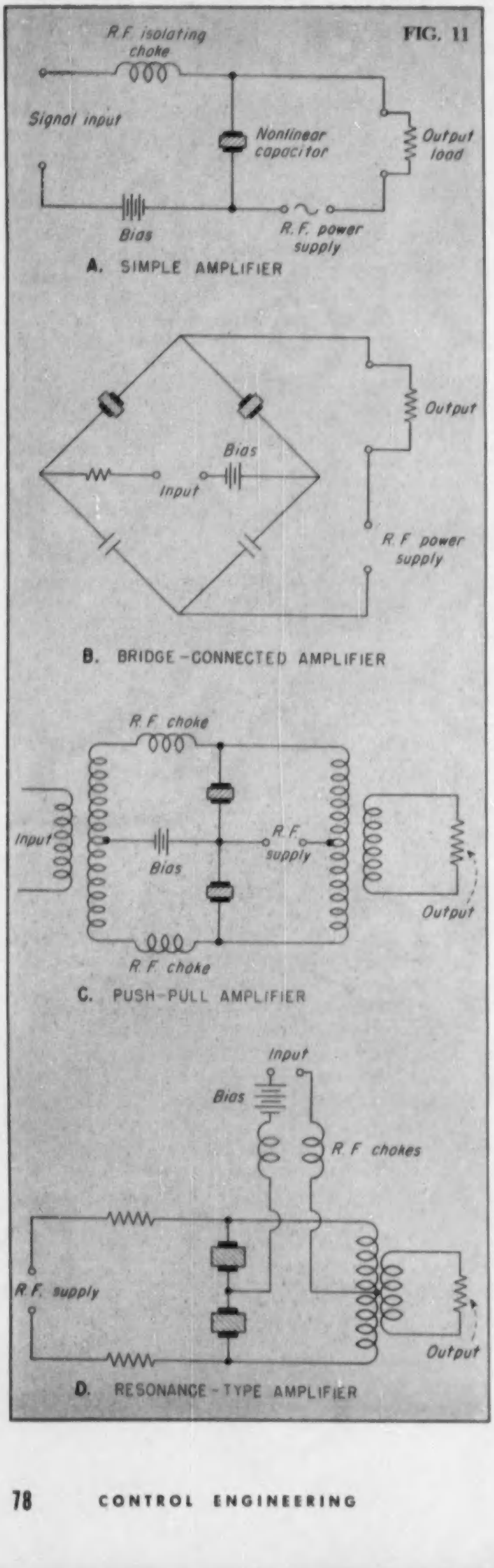
Figure 11A shows a simplified circuit of a dielectric amplifier to illustrate the basic principles. The nonlinear capacitor, the radio-frequency power supply, and the load form a simple series circuit in which the power-supply voltage is divided between the load and the capacitor. The input signal varies the bias on the capacitor, changing its effective impedance and thereby varying the portion of the supply voltage dropped across the capacitor. The voltage delivered to the load varies inversely. Because the signal is low-frequency compared to the power supply, the output is actually a modulated carrier which, when demodulated, yields an amplified version of the input signal.

The fixed dc bias is necessary because the capacitor decreases its capacitance for both positive and negative voltages. With no bias, therefore, the capacitance would dip for each half of an input sine wave signal, thus doubling the frequency instead of reproducing the original signal.

This frequency-doubling action is another use

SOME DIELECTRIC AMPLIFIER CIRCUITS

FIG. 11



for the nonlinear capacitor when this function is desired.

Remembering that the effect of the dc bias plus the low-frequency signal is to cyclically decrease and increase the size of the hysteresis loop being traversed by the high-amplitude rf power supply signal, one can explain the amplifier operation from the point of view of charge flow. Figure 6 is again applicable. The hysteresis loop shows the amount of charge flowing per cycle, representing a measure of the current flowing in the load. Maximum current is delivered to the load when the loop is largest, minimum when it is smallest. The alternate expansion and contraction of the loop with the input signal acts as a valve on the load current. The greater the change in the size of the hysteresis loop for a given input signal, the more gain is realized.

Figure 11B shows a bridge-connected dielectric amplifier using two nonlinear and two linear capacitors. With no signal the bridge is balanced. A signal adds to the voltage across one nonlinear capacitor and subtracts from the voltage across the other, upsetting the balance and causing the signal voltage to appear, amplified, in the output circuit as modulation on the rf carrier.

Figure 11C shows a pushpull dielectric amplifier.

Another type of circuit is pictured in Figure 11D. Here a tank circuit composed of a coil and two nonlinear capacitors is tuned just above or just below the power-supply frequency. The input signal shifts the effective capacitance so that the resonant frequency of the tuned circuit approaches and recedes from the supply frequency, demanding more or less power. The sharp slopes on the sides of the resonance response curve tend to increase the gain achievable from this circuit.

The basic function of the nonlinear capacitors in these amplifier circuits is modulation in one case and tuning in the other. Many other applications exist where tuning and modulation are the ends in themselves. For example, a sweep tuner may cover a frequency band by applying a periodic voltage to a nonlinear capacitor, thereby requiring no moving mechanical parts.

FERROELECTRIC MEMORIES

In a different class are the memory devices for storage of electrical information.

It was pointed out, with special reference to Figure 4, that the barium titanate capacitor remains in a charged condition after the application of a voltage. If these voltages are in the form of information pulses from a computing device, the barium titanate is capable of remembering whether or not it has received such a pulse. A simple circuit to illustrate the operation of a single memory cell is shown in Figure 12.

Consider a positive pulse as a writing pulse, impressing information, and a negative pulse as a read-

A MEMORY CIRCUIT

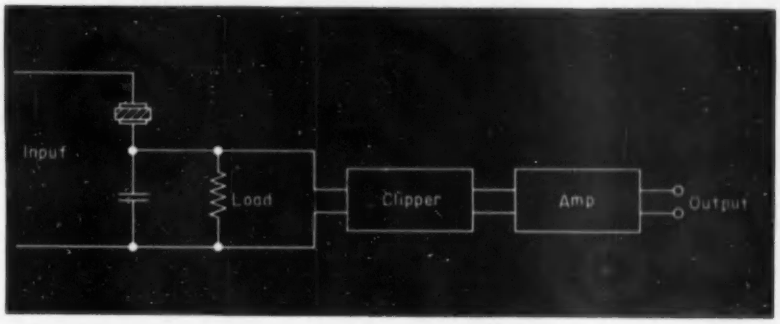


FIG. 12

ing pulse, probing for information. This is a binary system. All that is expected of the memory unit is that it answer yes or no when asked if it is storing information. No is as informative as yes.

Regardless of the initial condition of the nonlinear element, when a positive pulse is impressed it polarizes in the positive direction, point *A* in Figure 4. If another information pulse in the positive direction comes along, the memory element moves from point *A* to point *H* and back to point *A*. Since this is the saturation region, there is practically no flow of charge into the load. However, if a negative or reading pulse is applied, the element switches from point *A* to point *D* and then rests at point *E* after the pulse is past. The vertical distance from *A* to *E* is a measure of the flow of charge which surges into the load, producing an output pulse. This is fed into a clipper which is so biased as to reject any small output pulse present even when the element does not switch over.

If there is no storage, the memory element is in condition *E*. A negative reading pulse merely traverses the path *E* to *D* and back to *E*. The flow of charge is small and any small voltage appearing across the load is not passed through the clipper. Thus there is an output only when a reading pulse finds stored information.

Note that the readout is destructive in that the storage is lost. This can be remedied by a simple pulsing circuit which is triggered upon readout to restore an information pulse if required.

If the pulse widths are small, of the order of 0.1 or 0.01 microsec, the output pulse, indicating that the memory element is switching over because information had been stored, has the form of the input pulse with a long trailing edge. In this case a frequency-discriminating device such as an audio amplifier with a relatively low upper cutoff frequency will not pass the original pulse, but will see the trailing edge which is made up of lower frequency components. In this case, amplitude clipping is less efficient than frequency discrimination.

For memory elements the hysteresis loop should be square with vertical sides, a sharp knee, and a flat top. The flat top ensures that the output pulse is negligibly small unless the element switches over its dipoles. The sharp knee is important when the memory element is merely one bit in a large matrix. When reading one member in a matrix some voltage is fed to the other members. This voltage should be less than is required to actuate switching. Unless the knee is sharp, this critical voltage is not well-defined. The sharp knee and the flat top also assure high remanent polarization so that the output pulse, when switching does occur, is large and easily favored over noise or other unwanted signals.

Ceramic sheets have been developed which offer hysteresis loops approaching this ideal square loop, best approximated by the single-crystal type. The sheets are suitable for use as single memory bits or in small matrices, but are not yet satisfactory for full-scale matrix operation.

THE FUTURE FOR NONLINEAR DIELECTRICS

Still to be developed is a uniformly crystalline ceramic sheet with a sufficiently square hysteresis loop. By depositing conducting electrodes on the faces in the form of parallel lines, those on one face being perpendicular to those on the other, the intersections of these lines in the projected view form a grid of tiny nonlinear capacitors. A particular capacitor or memory bit is reached by selecting the two lines which cross at that point in a simple coordinate system. In this ideal case it would become possible to have thousands of memory cells in a ceramic "brain" within the area of, and only slightly thicker than, a postage stamp.

There are, at present, thin ceramic sheets of sufficiently enriched crystallinity to furnish a potential source of cheap small crystals. These may be of value in such applications as dielectric recording tapes.

Other developments point toward ceramics with greater nonlinearity or greater dielectric strength (so that stronger fields may be applied) and toward improving the methods of growing single crystals.

Although potentiometers are functionally simple, their large variety of electrical characteristics and mechanical configurations makes the problem of applying them a complex one. But by becoming familiar with pot types and characteristics, and the requirements of basic pot applications, you can simplify the job. A good procedure is recommended by author Gray.

- Find out whether a resistance pot will best satisfy requirements by comparing the characteristics of the various types, Table I, page 82.
- When you have decided to use a resistance pot, take a look at the available varieties in Table II, page 83.
- Review the eight basic system functions of potentiometers, page 86. Probably your application is similar to one or more of these basic functions, so you can quickly establish the important potentiometer characteristics.
- Make sure you haven't overlooked any important selection factors. Review those listed in Table IV, page 88.
- Learn how to recognize basic pot functions in complex systems by studying the examples starting on page 89.
- Follow a typical problem from the basic system configuration and specifications through the final selection of commercially available pots, page 91.

A Guide to Applying Resistance Pots

POTS REGULATE PRINTING TIME. Logarithmic pots in highly accurate exposure timing device for Kodacolor Printer. Rigid specifications required that pot conform to logarithmic function over a 6:1 ratio. (Eastman Kodak Co.).

HOLLIS L. GRAY JR., Technology Instrument Corp.

Potentiometers are electromechanical devices that develop an electrical output signal proportional to the product of an input electrical signal and some function of shaft angle. In the special but highly important case where the shaft angle function is a straight line, a potentiometer is called linear.

Potentiometers have become so important in the fields of computation and automatic control that a wide variety of more or less "standard" types has been developed, each with its distinct area of application. In addition, manufacturers are willing to design "specials" to customer specifications where existing types are not satisfactory. Thus, the user is faced with the formidable task of choosing, from the assortment of standards and special types, the one most suitable for his system. And since the potentiometer that is used often spells the difference between a workable and unworkable system, or between a complex and greatly simplified one, the selection procedure is important.

First, the basic potentiometer type must be chosen: Table I tabulates and describes the principal available varieties. Each of these has its own field of greatest utility, and it is necessary to scan this table prior to choosing a potentiometer for an unusual or especially stringent application. Of those listed, the resistance potentiometer is the most versatile and most widely used. It develops a shaft-responsive electrical signal by the motion of sliding a contactor or wiper along an energized resistance element. It is the most important potentiometer type because it is:

- functionally flexible, so that it can be used in innumerably diverse applications
- easily integrated with other elements of analog computers and electromechanical control systems
- reliable, and capable of withstanding the most severe environmental conditions
- economically available to very high accuracies, and in compact sizes representable by fixed parameters with predictable systems characteristics

Its principal competitor, the induction potentiometer, has some very unusual advantages, of which long life and infinite resolution are two, and often provides the only satisfactory solution to certain application problems. However, the complexity of the associated equipment required for high accuracy may make its cost prohibitive. With respect to quantity in use, the induction potentiometer runs a poor second to the resistance type and the gap is constantly widening.

But the choice is not simple, even when restricted to resistance potentiometers. Table II lists the principal varieties of resistance potentiometers: the specific application must be studied to determine the most suitable type. The following factors should serve as generally useful preliminary guides:

1. Single-turn and multi-turn potentiometers, using a moving contact on a wound mandrel, are by far the most common and generally useful variety.
2. Where a potentiometer is located *within* a closed loop, resolution (which affects stability) is an important selection factor. Otherwise, resolution limits can be established by accuracy specifications alone.
3. For highest accuracy in a minimum size, multi-turn potentiometers should be used.
4. Linear-motion potentiometers have the same accuracy and resolution as the rotary-motion type for equal lengths of resistance element.
5. Maximum resolution is achieved in potentiometers having long resistance elements (either through multi-turn construction or large diameter), and high resistance (so that fine resistance wire can be used).
6. In small single-turn units, the film-type resistance element affords comparatively high resolution. However, granularity does exist and must be accounted for in critical applications.
7. Low-torque potentiometers generally have high contact resistance (hundreds of ohms) as a result of the minimum contact pressure permitted on the resistance element. They cannot be used as variable resistors. Units with torque requirements as low as 0.003 oz-in. are commercially available.
8. In using ganged potentiometers, driving torque, phasing between cups, and minimum backlash between cups must be considered.
9. Slide-wire high-resolution pots are limited in maximum resistance. Where highest resistance is required, the small diameter of the slide wire results in reduced life.
10. Potentiometers are available to meet the most rigorous military environmental conditions; upper temperature limits have reached 350 F and higher.

TABLE I TYPES OF POTENTIOMETERS AND HOW THEY WORK

RESISTANCE POTENTIOMETERS

The resistance pot uses a sliding contact or wiper on a resistance element. It is a flexible component, can be used on ac and dc, operates to very high frequency ranges, introduces no distortion of the output signal, and can be manufactured to high accuracies at a relatively low cost. Its principal limitations are: limited life due to sliding contact, poor ratio of output to input impedance, and noise generation at the wiper.

INDUCTION POTENTIOMETERS

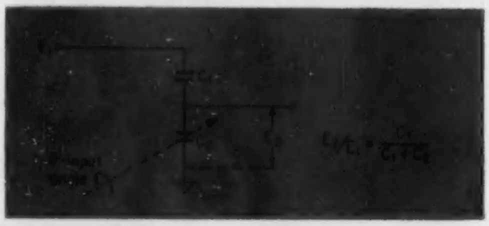
Action is obtained by varying the mutual inductance between a primary coil and an output or secondary coil. The instrument is distinguished by exceptionally long life (hundreds of millions of cycles at speeds up to several thousand rpm). Resolution is infinite, and accuracies are comparable to resistance pots. By its nature, it provides isolation between input and output. Its principal limitation is the expensive electronic auxiliary equipment required for phase correction and temperature and nonlinearity compensation. It has a low ratio of output to input impedance, and is not as load-sensitive as the resistance pot.

INDUCTIVE POTENTIOMETERS

This is essentially a variable auto-transformer, with a contact for varying the output tap point. Present units avoid a sliding action by using a rolling wiper. Life is somewhere between that of the resistance pot and the induction pot. The ratio of output impedance to input impedance is extremely low, so that high accuracies can be achieved even when heavily loaded. Properly designed units have practically infinite resolution, and thus are suitable for use in high-gain servo systems. Their principal limitation is their size, large in comparison with equally accurate resistance or induction pots.

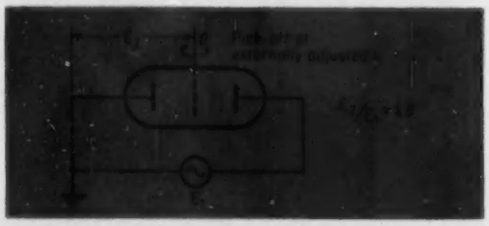
RELUCTANCE POTENTIOMETERS

Mutual inductance of two coils is varied by moving a magnetic slug. The differential transformer, responding to linear-motion inputs, is a useful special variety of this unit. Since there is no contact with the rotor, the reluctance pot is simple, rugged, and long-lived. This, and the following types, are not as generally used as first three above.



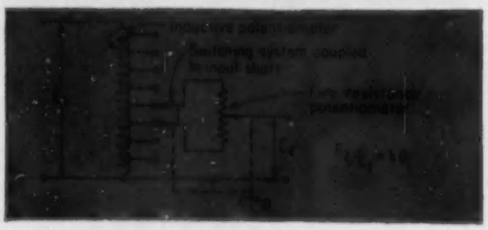
CAPACITIVE POTENTIOMETERS

Capacitance is varied by an angular shaft motion. By its nature, it is useful as a control element in high-frequency circuits. It has been used in computers for the generation of linear and nonlinear functions. Shielding is an important prerequisite to satisfactory operation.



DIELECTRIC POTENTIOMETERS

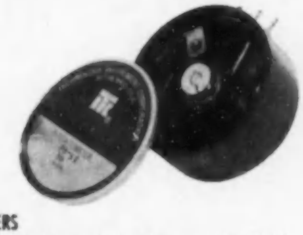
Recently developed, their action is obtained by varying the position of a pickup point or tap in a current-carrying field. They are principally used on ac because of ionization problems. The total resistance of a dielectric pot varies considerably with temperature. However, the accuracy of the tap voltage as a percentage of applied voltage can be held to very close tolerances. Infinite resolution and unlimited life are the two major features.



COMBINED TYPES

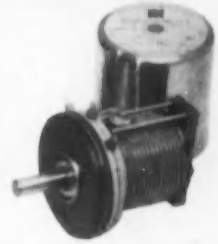
Many potentiometers are combinations of some of the above types. A common form includes one of the above types, suitably tapped, with a fine potentiometer interpolating between taps. Synchronized switching is required in this application. Accuracies of 0.003 per cent have been achieved this way.

TABLE II VARIETIES OF RESISTANCE POTENTIOMETERS



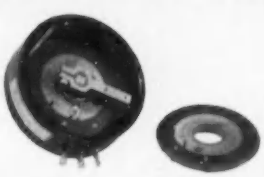
SINGLE-TURN POTENTIOMETERS

Most common variety, available in small sizes in accuracies within 0.1 per cent. Because of limitations in wire size, the resolution of this type pot cannot exceed 1 part in 2,500 per inch of diameter. Life is longer than that of the multi-turn units, and their small angular motion allows them to be operated heavily geared down, thereby reflecting negligible friction and inertia to a servomotor. Large diameters of 3 or 4 in. are not uncommon where high accuracies are required. This type is especially adaptable to ganging. Maximum resistance values, readily obtainable with stable, low-temperature coefficient wire, range from 25 K for ⅞ in. diam to 200 K for 3 in. diam. Higher values are obtainable in special cases.



MULTI-TURN POTENTIOMETERS

Used where high accuracy and resolution are required in a minimum diameter. Because they must be operated at N times the speed of a single-turn pot, they often introduce substantial loading on a small instrument servomotor. With a large total angular travel, input gearing need not be as precise as for the single-turn equivalent. These units must always incorporate stops to limit servomechanism travel. Units are available with up to 60 turns. Accuracies and resolutions of a few hundredths of one per cent are within reach of a ten-turn unit.

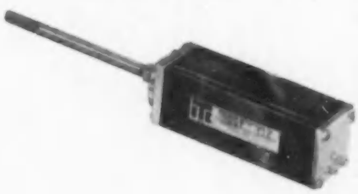


SLIDE-WIRE POTENTIOMETERS

Single slide wire serves as the resistance element, with a principal advantage being very high resolution in small sizes. Resistance in a given frame is limited by the length of wire. The thin wire needed for high resistance results in wear and reduced life. The slide-wire construction is often used in multi-turn pots where the additional active length permits practical resistance values. A typical 1.8 in. diam unit has a resistance of 250 ohms/turn. Larger diameters are used where higher resistance is needed.

LOW-TORQUE POTENTIOMETERS

Useful where the output of a transducer can directly drive a pot, often eliminating a servomechanism. Their contact resistance is high (up to several hundred ohms), and they are sensitive to vibration. In the lowest torque units, with sensitivities down to a few thousandths of an oz-in., jewel bearings must be used. Very low-torque units are of the single-turn variety, and maximum available resistance values correspond to the values for that category.



LINEAR-MOTION POTENTIOMETERS

Where the displacement to be measured is linear, the rack and pinion required for conversion often can be avoided by using this type pot. As with the rotary pot, resolution and accuracy are limited by the length of the resistance element. Thus a linear motion pot 2½ in. long performs approximately the same as a 1 in. diam rotary pot. Linear units require careful mechanical design to achieve good rigidity and repeatability with a minimum of friction.

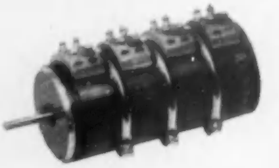
FILM-TYPE POTENTIOMETERS

A variety of high-resolution potentiometers has been developed using deposited metal, carbon, or conducting-plastic films. Resolution is better than the best wire-wound pots by two or three times (excepting the slide-wire type). The total resistance of these units, however, is not nearly as constant with temperature and aging. Experimental work is still being carried on, with high stability under extreme environmental conditions a primary objective. Carbon-film pots are available to 100 K in a 1 1/16 in. diam. Very low values (below a few hundred ohms) cannot be obtained without sacrificing other qualities. Carbon-film pots are not usually used as variable resistors because of high end resistance. Metal-film pots have higher resistance in a given size than wire-wound units,

TABLE II Continued

TRIMMER POTENTIOMETERS
Both metal-film and wire-wound pots are used for trimming and calibration purposes. They are characterized by extremely small size, a high degree of stability, and some kind of device for locking the setting after adjustment.

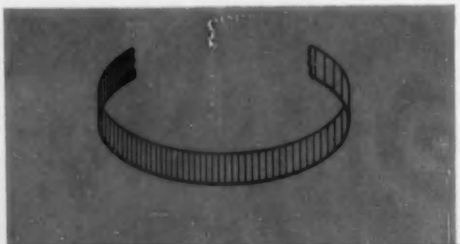
NONLINEAR POTENTIOMETERS
Used where nonlinear functions of shaft rotation are required. They may be considered as electrical "cams". Because of the many ways of achieving nonlinearity, Table III is devoted to this type.



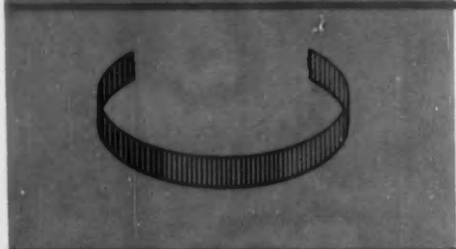
MECHANICAL VARIATIONS
A great number of mechanical variations, based on such factors as type of mounting, output shaft, provision for ganging, inclusion of switching circuits within the potentiometer, etc., are available, or can be specially designed. Four ganged single-turn pots are shown here.

TABLE III

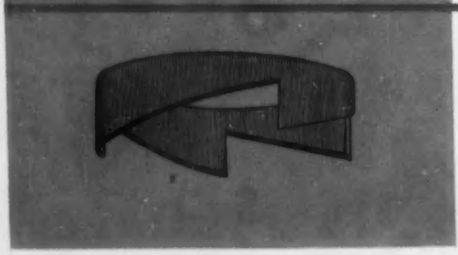
HOW POTENTIOMETERS GENERATE NONLINEAR FUNCTIONS



VARIABLE WIRE SPACING
Wire spacing on mandrel is increased or decreased, depending on the nonlinear function being generated. Resolution varies with spacing.

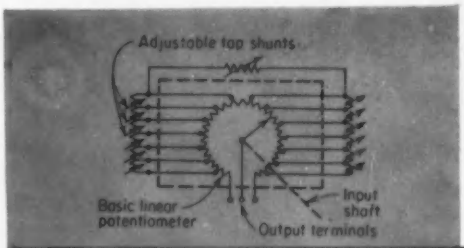


VARIABLE WIRE SIZE
Different wire size in sections of the resistance element permits change in output slope.

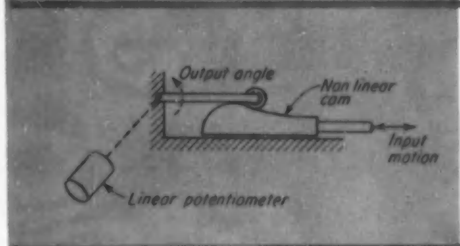


VARIABLE-WIDTH CARD
Mandrel on which resistance element is wound has a nonuniform width, corresponding to the nonlinear function.

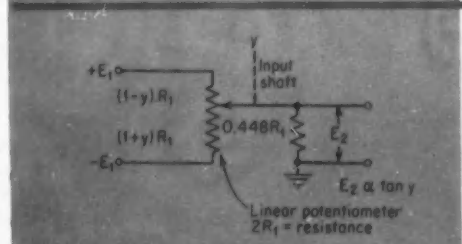
TABLE III Continued



TAPPED POTENTIOMETER WITH SHUNT RESISTORS
Convenient and moderately accurate method of establishing a nonlinear functions as a series of straight lines. The greater the number of taps, the closer the approximation.

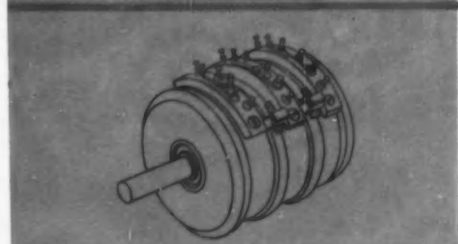


NONLINEAR DRIVING LINKAGE OR CAM
Often used to develop a sine or other nonlinear function from a linear potentiometer.

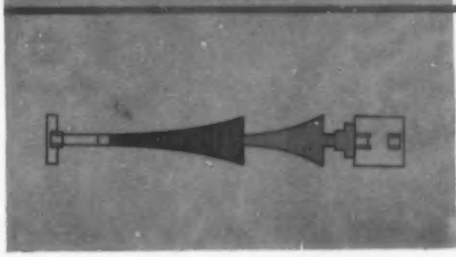


POTENTIOMETER WITH SUBSTANTIAL LOAD
A loaded potentiometer with a network of fixed resistors develops a limited but useful variety of nonlinear functions.

SPECIAL ARRANGEMENTS OF WIRE ON FORMS
A contact moves across the flat surface of a specially shaped element to develop the required nonlinear function. Film and wire-wound sine-cosine pots are typical varieties.

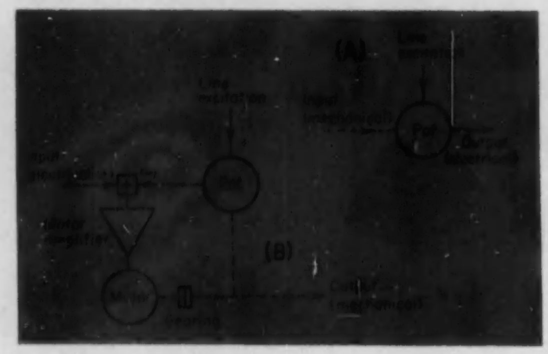


GANGED POTENTIOMETERS
Potentiometers feeding into one another in cascade can accurately develop certain limited functions. Raising to a power is particularly convenient.



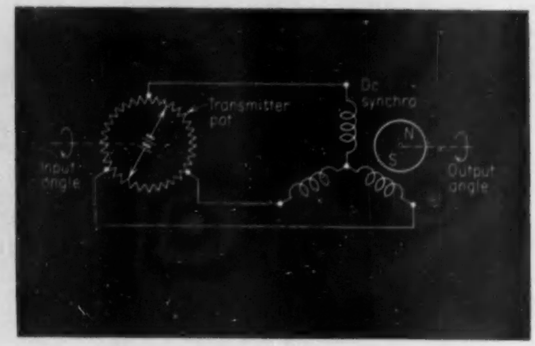
COMBINATION OF METHODS
Frequently the above techniques can be combined to give high accuracy, or a specially high degree of nonlinearity. The figure shows an example, a pot mandrel using a stepped, variable-width card and different wire size where the required slope of a contoured design is beyond practical limits.

THE EIGHT BASIC SYSTEM FUNCTIONS



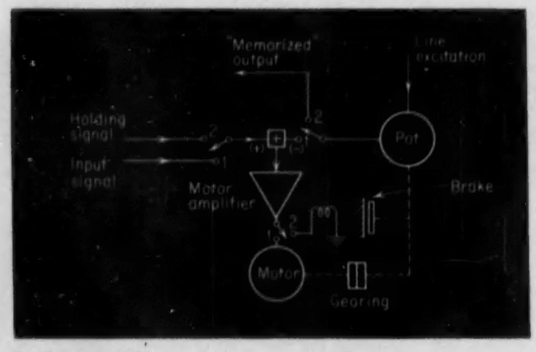
1. DATA CONVERSION

The importance of the electromechanical computer for analog computation and automatic control has established the potentiometer in a leading role as a converter between shaft angle and electrical signal. (A) shows the mechanical to electrical conversion, and (B) the electrical to mechanical conversion. The accuracy must be sufficient to meet the requirements of the application, while resolution must be consistent with the stability requirements of the closed loop. Note also the possibility of multiplying or dividing with line excitation as one variable.



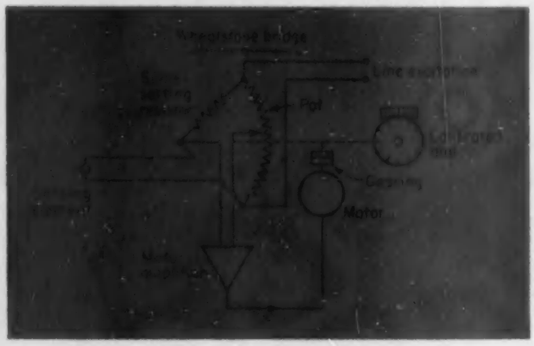
2. ANGLE TRANSMISSION

Since the pot must do work in providing the energy for positioning the dc synchro, it must be capable of sustaining a large amount of heat dissipation. Inherently, open-loop systems of this type are not highly accurate. Potentiometer-shaft frictional torque is apt to be appreciable since heavy contacts are required for current conduction. However, in the open-loop system, resolution is important only as it affects accuracy.



5. NULLING

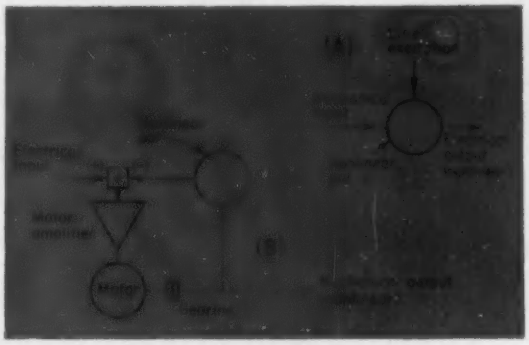
In nulling circuits, a servomechanism positions a potentiometer so that it bucks out an input signal. Since precise nulling is important in a high-gain servo, resolution must be adequate if oscillation is to be avoided. The diagram shows a pot as a nulling device in a "memory" circuit. After the pot is positioned to balance the input signal, it may be locked in that position by a brake. Then the "memorized" output voltage may be switched to another circuit.



6. BALANCING

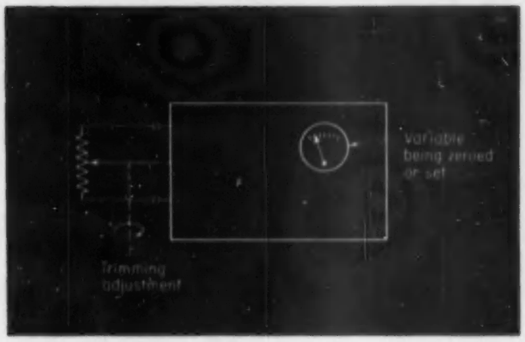
When used as a balancing device, potentiometer accuracy must be consistent with the requirements of the application. High resolution is also necessary because of the closed loop. In the diagram, balancing-potentiometer shaft position is an indication of the quantity being measured.

Establishing optimum specifications is a complex task because of the great range of possible applications. Factors that are relatively unimportant in some applications become primary in others. The following describes eight basic functions, each requiring its own distinctive potentiometer characteristics. These eight are comparable to the large majority of complex potentiometer applications in industrial and military equipment. Once a basic pot function is recognized in a complex system, potentiometer specifications suggest themselves.



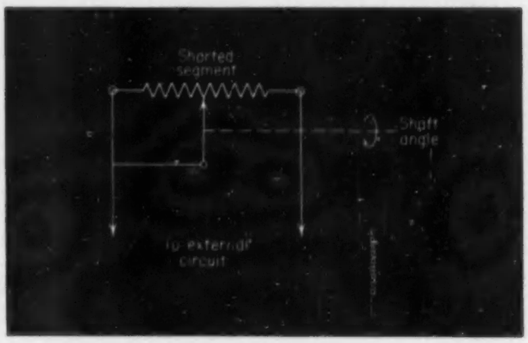
3. FUNCTION GENERATION

A potentiometer can develop a nonlinear function of a mechanical or electrical input in addition to the normal straight-line characteristic. (A) and (B) show the mechanical-to-electrical and electrical-to-mechanical conversions, respectively. The requirements are similar to those for data conversion. Depending on the way the nonlinearity is developed, resolution may be a function of shaft position, in which case stability must be investigated under worst conditions. In (B), servomechanism stiffness can vary according to the potentiometer gradient. Adequate stiffness must be achieved under the sloppiest conditions, while at the same time stability must be maintained at the other high-gain extreme. Nonlinear servo techniques ease the design problem.



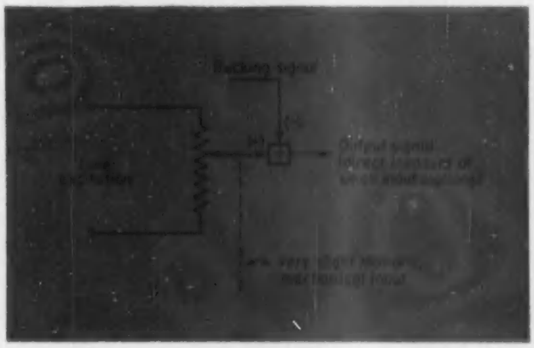
4. TRIMMING

Pots can be used to make circuit adjustments where normal variations in the system cause shifts in calibration. Principal trimmer characteristics are precise maintenance of setting and adequate resolution to meet the finest adjustments required in an application. Where these units are used as variable resistance elements, rather than as straight voltage dividers, low-temperature coefficient and low contact resistance are also necessary. Since trimmers are often used in electronic equipment, they are designed to operate at temperatures up to 350 F. Locking features are required to maintain the initial setting. Since accuracy is not a factor, they can be designed extremely small. Recent designs use metal films as the resistance element.



7. VARYING RESISTANCE

When used as a variable resistance, constancy of total resistance and low contact resistance are important. Resolution affects only the fineness of the adjustment.



8. DETECTING SMALL MOTIONS

Pots can be used to detect small motions in open- and closed-loop systems. Typical examples are pressure pickups, gyro pickups, accelerometers, and strain gages. Resolution and low noise level are principal factors, total resistance and accuracy less important.

HOW TO SELECT A POTENTIOMETER

The principal selection factors for resistance potentiometers are surveyed in Table IV. In specific instances, as noted previously, certain of these selection factors are of prime importance, while others may be safely ignored. Awareness of the basic system functions and use of the preceding tables assure a step-by-step selection procedure.

I STUDY THE APPLICATION—Examine the system and establish pot application similarity to one or several of the basic functions. This will reveal the key selection factors.

II ESTABLISH POTENTIOMETER TYPE—Check Table I of basic potentiometer types to determine the suitability of a resistance potentiometer. Where special performance is required, Table II will show which type resistance pot is best.

III PICK A RESISTANCE POTENTIOMETER—Based on required system performance, numerical values can be assigned to the key selection factors. This step requires a good understanding of the relationship between these numerical values and system performance.

IV SELECT MODEL—Search the catalogs of companies manufacturing resistance potentiometers of the type selected, and choose a unit meeting the specifications. Since performance limits in the potentiometer field are being continually bettered, it may be advisable in the most stringent applications to consult directly with the manufacturer.

V REVIEW SELECTION FACTORS—Check the selected potentiometer against the complete list of selection factors in Table IV. To the engineering specifications must be added the ability of a manufacturer to deliver in production quantities according to specifications, the availability of additional sources, the previous successful application of the selected potentiometer type, etc.

COST—The cost of resistance potentiometers is related primarily to degree of standardization and volume of production. For general-purpose medium-precision work, ten-turn potentiometers of approximately 1 13/16 in. diam, and single-turn units of 2 to 3 in. diam are most economical. Less popular units, such as the zero-resolution or very-low-torque types, or special designs, can easily cost five to ten times the price of the general-purpose ones. Trimmer units cost roughly one-fourth the price of the low-priced potentiometers.

TABLE IV CHECK LIST OF SELECTION FACTORS

ELECTRICAL CHARACTERISTICS

TYPE OF POTENTIOMETER—Check against available varieties of resistance potentiometers as listed in Table II.

LINEARITY, ZERO LOCATION, AND TRIMMING—These relate to the problem of fitting the best straight line to the actual output curve of a potentiometer. The best straight line is that which gives minimum error. Trimming resistors in series (and also in parallel) with the potentiometer, and arbitrary choice of zero location, make this optimum fit possible. Tolerances for accomplishing this adjustment must be specified in the pot circuit design.

TOTAL RESISTANCE AND TOLERANCE—Total resistance is related to heating and also to loading, since high-resistance potentiometers can only be loaded by even higher resistance potentiometers. Unless the resistance of the loading pot exceeds the resistance of the loaded pot by at least a factor of ten, there is apt to be significant loading error. Thus, minimizing the resistance of the first pots in a chain is normal practice. Minimum resistance is, however, limited by heating effects, and by the poor resolution of low-resistance units with their fewer turns of wire. Another significant factor is the frequency error resulting from stray capacitance that becomes effective in high resistance circuits. In several-hundred-thousand-ohm pots, errors due to stray capacitance can amount to several tenths of a per cent at 400 cycles.

CONTACT RESISTANCE AND NOISE GENERATION—Noise at the contact behaves like an additional voltage source and a variable resistance in series with the output lead. When a pot is loaded for use as a variable resistor, contact resistance may be extremely important. When a pot is feeding a high-impedance vacuum-tube circuit, noise is less important but still significant, in that it may saturate the amplifier. Also, excessive noise may generate radio interference.

ACCURACY OF TAP LOCATION—Where taps are used to increase pot flexibility, tap location accuracy may be significant. This must be tied to a specific application.

RESOLUTION—In wire-wound pots (not slide-wire types), the output varies in a step-like fashion with shaft position as the wiper arm moves from one wire to the next. This step-like behavior corresponds to infinite slopes at discrete points, which means infinite gain in a servo. These points of infinite slope may become points of oscillation when the unit is used in closed-loop systems. Resolution should be kept to a fraction of the allowable error.

GRANULARITY—This applies only to film-type potentiometers, and corresponds roughly to resolution in wire-wound units. It relates to the film's crystalline structure.

TEMPERATURE COEFFICIENT OF RESISTANCE—This is related to the tolerance imposed on total resistance, since high-temperature coefficients cause total resistance to vary widely with temperature.

MECHANICAL CHARACTERISTICS

Permissible environmental conditions
Aging
Life under required duty cycle
Sensitivity to shock and vibration
Required driving torque
Physical suitability: size, mounting dimensions, shaft requirements, etc.
Useful angle of rotation
Shorting or nonshorting characteristics of terminals

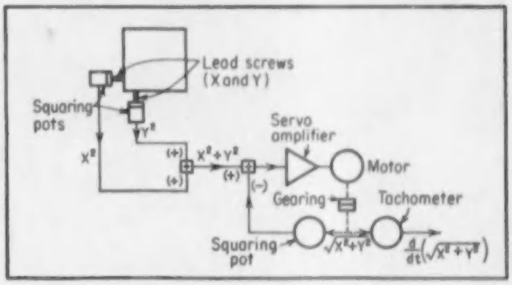
MISCELLANEOUS FACTORS

Cost
Availability
Experience of others with this potentiometer

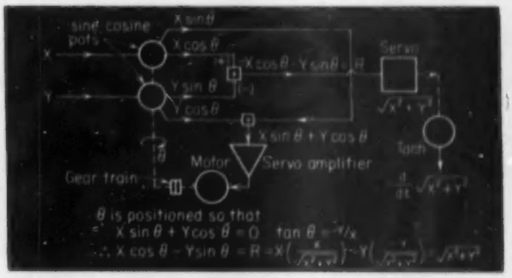
DETERMINE THE BASIC POT FUNCTION IN 10 TYPICAL APPLICATION CIRCUITS

The following application circuits emphasize the purpose of the overall system rather than the potentiometer function. They are included to show how the basic pot function can be recognized in relatively complex circuits. Once the basic function is determined, the key specifications are apparent.

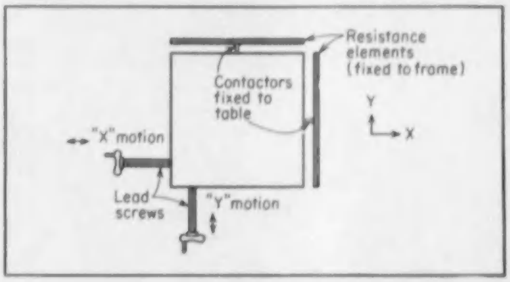
1. CIRCUIT FOR DETERMINING TANGENTIAL CUTTING SPEEDS
The table of a milling machine is being oriented by the motion of *X* and *Y* leadscrews to permit cutting a contour, such as a plate cam. The assembly of components delivers an output voltage proportional to the tangential speed of the cam-cutting operation. The squaring pots on the lead screws are function generators, with accuracy important but resolution not a problem. The pot in the feedback loop is both a function generator and balancing device. Both high accuracy and high resolution are required. Servo has variable stiffness as noted in section on basic system functions.



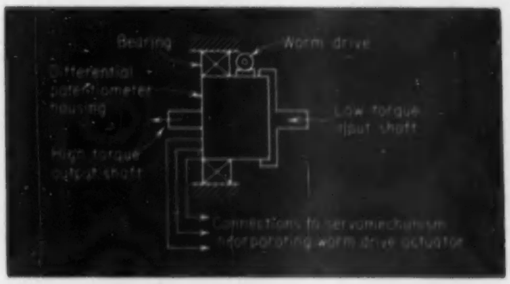
2. ALTERNATE CIRCUIT FOR DETERMINING TANGENTIAL CUTTING SPEED
In this alternate computational scheme, two trigonometric function-generating pots supply the nonlinear functions in lieu of the three squaring pots in the previous diagram. Since they are both in the loop, resolution and accuracy are problems. Again, variable servo gain (depending on the magnitude of *X* and *Y*) is characteristic of this type system. An additional linear pot is also required in the servo to convert the electrical signal, *R*, into a shaft rotation.

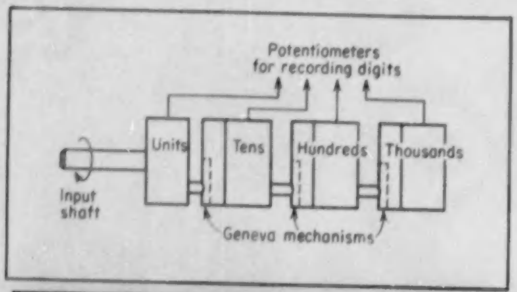


3. TABLE-POSITION INDICATION
Linear-motion potentiometers convert mechanical displacement to a proportional electrical signal. In this data-converting function, accuracy is the problem, not resolution.



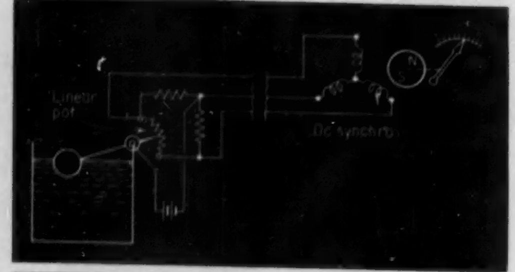
4. TORQUE AMPLIFIER
Differential potentiometer used for torque amplification. Motion of low-torque input (wiper) shaft produces an output signal, which, amplified, actuates the worm drive and delivers a high torque output. Performs a nulling function; pot accuracy and total resistance unimportant, resolution critical.





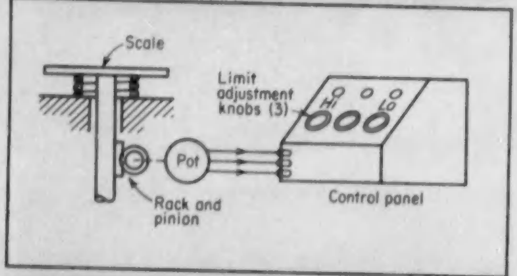
5. REVOLUTION COUNTER

Potentiometers for data conversion. The voltages from the four potentiometers indicate corresponding digits. In this application, the digital nature of the output minimizes pot requirements in general.



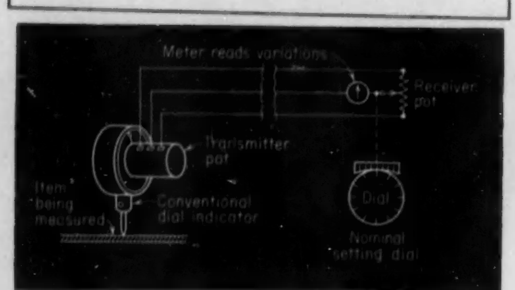
6. LIQUID-LEVEL INDICATION

Remote transmission of liquid level by means of potentiometer and dc synchro. The basic function is angle transmission. Resolution is unimportant, and accuracy better than a few tenths of a per cent is unnecessary due to friction and intrinsic system errors.



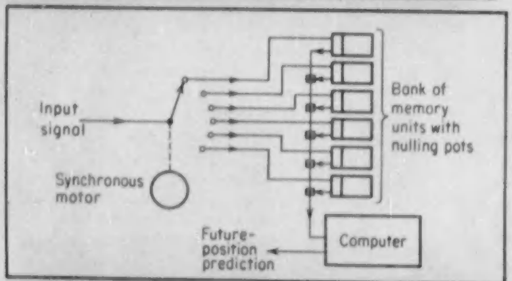
7. HI-LO WEIGHT INDICATOR

This arrangement is useful in repetitive industrial weighing operations. The pots in the control panel, preset to required limits, buck the transmitting pot coupled to the scale. Basic function is detecting small motions, so that the transmitting pot must have sufficient resolution to detect small variations from the preset nominal weight. Total resistance and accuracy are less important.



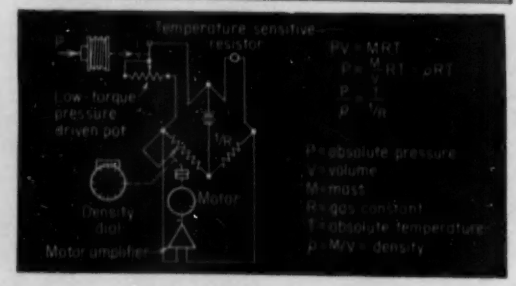
8. THICKNESS GAGE

Pot on conventional dial indicator simultaneously detects small motion variations, and remotely transmits them to an output meter. Transmitter pot must be of low-torque variety and have high accuracy. Accuracy of meter reading depends completely on accuracy of transmitting pot. Receiving pot is not critical.



9. MEMORY UNITS

Potentiometers, used here as memory units, serve as nulling devices. The input signal is switched in turn to the servo-actuated bucking pots. These bucking pots thus "remember" a uniformly spaced sequence of input signals, which, when applied to the computer, permit prediction of the input signal at some given future time. Accuracy and total resistance are unimportant, but resolution must be adequate to avoid servo instability.



10. AIR-DENSITY COMPUTER

Computer operates on the perfect gas law, uses two potentiometers as variable resistors. Bellows-driven pot must be of low-torque variety and highly accurate. Balancing potentiometer coupled to the density dial must have good resolution to avoid closed-loop instability.

SPECIFYING THE POTS IN A TYPICAL SYSTEM

A Description of the System —

The system must develop an output voltage proportional to temperature in the range 20 C to 80 C. The output voltage is for control purposes. The circuit uses a self-balancing Wheatstone bridge, with a thermistor temperature-sensing element. Figure 1 shows the resistance variation with temperature for the selected thermistor. Since the temperature characteristic of the thermistor can be defined mathematically, this relationship (noted on Figure 1) can be used in the analysis of the system.

Because of the highly nonlinear character of the thermistor bridge, sensitivity will tend to vary with temperature. To counteract this, the self-balancing bridge must be designed to maintain uniform servo stability at any temperature in the operating range. The output voltage is to be zero at 20 C and 100 volts at 80 C. Temperature measurement must be accurate within plus or minus 1 deg C, corresponding to 10/6 volts at the output. In terms of output accuracy, this is a relatively crude 1 2/3 per cent.

A schematic diagram of the proposed self-balancing bridge is shown in Figure 2. This bridge contains three potentiometers, P_1, P_2 and P_3, that must be specified. Figure 3 describes the mathematics of the system. For good bridge sensitivity with low voltage dissipation in the bridge elements, the general properties of a bridge suggest that

$$R_3 = R_4 = R$$
$$R_1 = R_2 \text{ at bridge balance}$$
$$R >> R_1, R_2$$

As shown in Figure 3, the nature of the resistance-temperature variation of the thermistor indicates that bridge sensitivity tends to decrease with increasing temperature. Thus, potentiometer P_2, whose setting is a function of temperature, is included to compensate for this change in sensitivity and maintain constant gain as temperature varies. This constant gain will approximate the lower gain encountered at the maximum temperature extreme, since P_2 cannot amplify, but can only attenuate. If R is much greater than R_1 and R_2 at the higher temperature limit, then the uncontrolled gain at this point will be increased. The reduction in gain at low temperatures resulting from a reduction in the inequality simply means less attenuation will be required of P_2 in this region. Thus, if R_1 is 156 ohms at 80 C, a suitable value for R would be 500 ohms.

The system is simplest if P_1 is a nonlinear potentiometer with exact correspondence to R_1 (the thermistor resistance) as a function of temperature. Thus, shaft angle c will be a linear function of temperature, and P_3, the output potentiometer, will be linear. There are advantages to selecting P_1 with the proper nonlinear function. Since output shaft angle and temperature are proportional, servo stiffness (the error per unit displacement of the controlled shaft) and temperature sensitivity

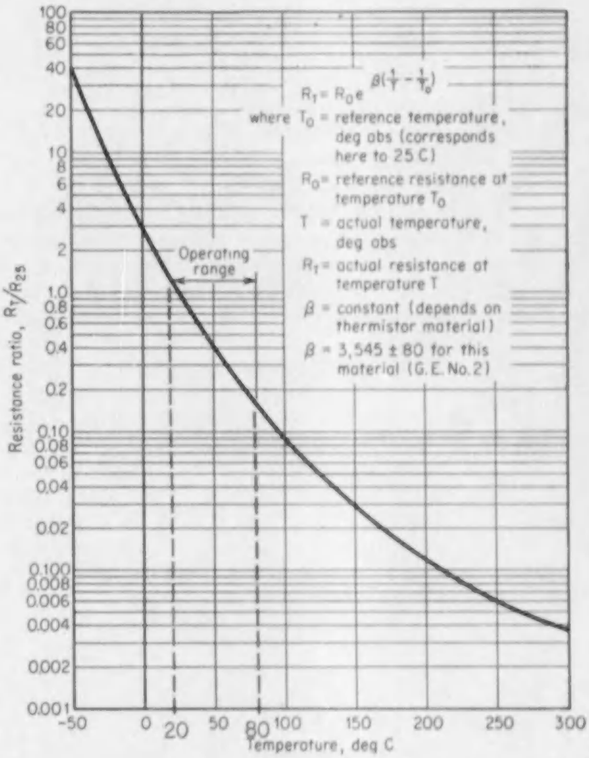


FIG. 1. Temperature characteristics of thermistor, expressed graphically and mathematically.

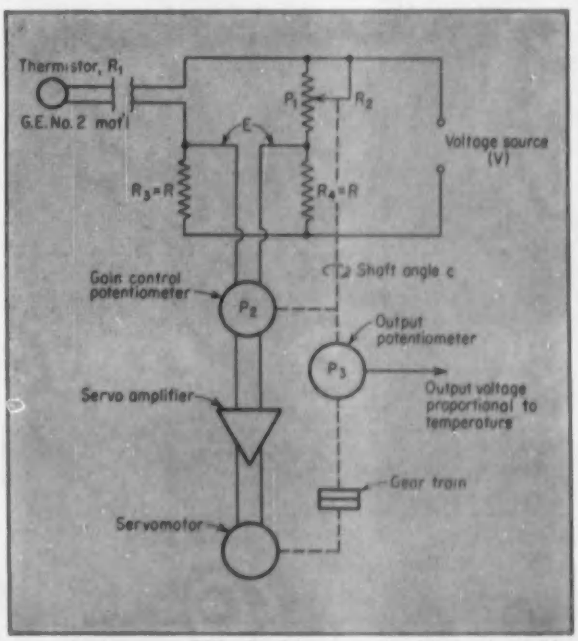


FIG. 2. Schematic of self-balancing bridge.

(the error per unit temperature change) are equal and (with the help of P_2) constant.

—and the Step-By-Step Selection of the Pots

I—STUDY THE APPLICATION—In this step, specific potentiometer application must be compared with the basic system functions. This reveals the key selection factors. Table V summarizes this step for the problem at hand.

II—ESTABLISH POTENTIOMETER TYPE—Because the thermistor behaves as a pure resistance, the use of resistance potentiometers throughout is suggested. A check of Table I reveals that the specialized characteristics of the nonresistive types are not required. A review of Tables II and IV indicates the following resistance pot types:

P_1—Large-diameter, single-turn, shunted-tap nonlinear pot required. Because of the high degree of nonlinearity, a combination of shunted taps and some other internally constructed nonlinearity may be required. See Table III.

P_2—A single-turn, low-accuracy, nonlinear pot required. A shaped card will probably give suitable characteristics.

P_3—A standard ½ per cent linear potentiometer suitable here.

III—PICK A RESISTANCE POTENTIOMETER—Based on the above reasoning, the specifications are as summarized in Table VI.

IV—SELECT MODEL—The potentiometers defined by the above specifications do not represent extremes of performance, and suitable types can be ordered from a number of manufacturers. Table VII lists TIC models that fulfill all requirements.

V—REVIEW SELECTION FACTORS—A check of the selected potentiometers is made against the complete list of Table IV.

Fig. 3. THE MATHEMATICS OF THE THERMISTOR BRIDGE BALANCE

Refer to Figures 1 and 2 for symbol definitions. In this analysis, the loading of the bridge by P_3 is negelected. Then, by inspection:

$$\frac{R_1}{R_1 + R} - \frac{R_2}{R_2 + R} = E/V$$

For approximately balanced conditions, where $R_1 \simeq R_2$

$$E/V = \frac{R(R_1 - R_2)}{2(R_1 + R)} = k$$

As R increases, it can be seen that E/V (sensitivity) increases to a limiting value of $(R_1 - R_2)/2$. Thus, at high temperatures, where sensitivity tends to fall, it is advisable to specify $R >> R_1, R_2$.

R_1 is the resistance of the thermistor, which is related to temperature as follows: (See Figure 1)

$$R_1 = R_T = R_o e^{\beta(1/T - 1/T_o)}$$

To determine bridge sensitivity to temperature change, differentiate R_T with respect to T.

$$\frac{dR_T}{dT} = - \frac{\beta}{T_2} R_o e^{(\beta 1/T - 1/T_o)} = - \frac{\beta R_T}{T^2}$$

To determine the output for a small change, dT, in temperature, rewrite the expression for k as follows:

$$dk = d(E/V) = \frac{R dR_1}{2(R_1 - R)}; \; dR_1 = - \frac{\beta R_1}{T^2} dT, \text{ and therefore}$$

$$\frac{dk}{dT} = \frac{-R\beta R_1}{2(R_1 - R)T^2}$$

This shows the variation of output voltage with temperature change, and is a measure of sensitivity. Sensitivity decreases continually with increasing temperature, as noted above. The gain control potentiometer must vary its attenuation as a function of temperature (or shaft angle c) in a reciprocal manner, to insure uniform temperature-insensitive loop gain. Thus, the ratio of electrical output to mechanical input for P_2 must vary as

$$\frac{2(R_1 - R)T^2}{\beta R_1}, \text{ where}$$

$$R_1 = f(T) = f(c); \; R \text{ and } \beta \text{ are constants}$$

At very low temperatures where R_1 approaches infinity, the output impedance of the bridge as seen at P_3 approaches 250 ohms. Loading will be no problem if P_3 is assigned the convenient value of 5,000 ohms.

TABLE V STUDY THE APPLICATION AND DETERMINE BASIC POT FUNCTIONS

POTENTIOMETER	BASIC SYSTEM FUNCTION	KEY SELECTION FACTORS
P_1 Balancing Potentiometer	Balancing, resistance variation, and function generation	Good resolution required since it is in closed loop. Resistance accuracy must correspond to well under the equivalent of 1 deg temperature change, if overall 1 deg C accuracy is to be maintained. Because of nonlinearity, resolution may be poorest at high temperature, where rate of change of resistance with shaft angle is minimum. (This depends on method used to achieve nonlinearity.) Resolution at maximum temperature should exceed accuracy requirement by at least a factor of two. Contact resistance must be kept low because of variable resistance aspect of application.
P_2 Gain-Control Potentiometer	Function generation	Noncritical, since it merely adjusts loop gain. Resistance variation with shaft angle should maintain loop gain independent of shaft angle. Resolution is also unimportant.
P_3 Output Potentiometer	Data conversion (linear)	Resolution requirement must be merely adequate to insure accuracy, since there is no closed loop in the mechanical-to-electrical data conversion. Since overall accuracy is plus or minus 1 deg C, pot accuracy of plus or minus ¼ deg C is adequate (corresponds to about 0.4 per cent).

TABLE VI ESTABLISH POT SPECIFICATIONS

P_1 Total resistance 964 ohms. Must be capable of matching thermistor resistance characteristic to within a fraction of the ohmic equivalent of 1 deg C at all temperatures in the range 20 C to 80 C. Contact resistance must not exceed a few ohms, since unit is used as a variable resistor. A single-turn nonminiature pot should provide adequate resolution for this medium precision application. The total resistance of the purchased pot, and the required precision, must be related to the method of achieving the nonlinearity and the techniques for trimming.

P_2 Wire-wound pot, used as a voltage divider, requires less degree of nonlinearity than P_1. Conformity of plus or minus 5 per cent should be adequate. Figure 3 suggests a resistance of 5,000 ohms. Manufacturer's standard tolerance of plus or minus 5 per cent total resistance satisfactory.

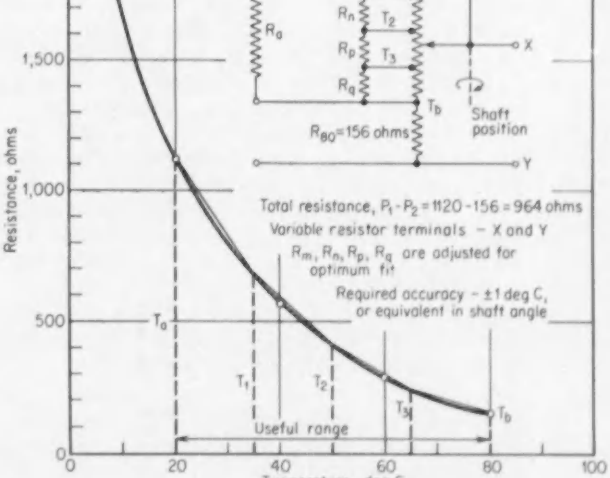
P_3 A standard single-turn ½ per cent pot is required. Since the unit must be capable of dissipating heat corresponding to 100 volts, the lower limit of permissible resistance is established by power rating. The usual 5 per cent tolerance on total resistance is suitable. Resolution is noncritical.

TABLE VII SELECT COMMERCIALLY AVAILABLE MODELS

POTENTIOMETER	TIC MODEL NO.	DESCRIPTION
P_1	RVC2*	2-in. precision pot, with three equally spaced taps for shunting resistors to approximate nonlinear functions. This unit has uniform resolution, and since loop gain is kept constant by P_2, stability should be no problem. Contact resistance is a fraction of an ohm. The servo-mount construction is well suited for integration in the closed-loop assembly.
P_2	RV2	2-in. general-purpose pot with shaped card for achieving the nonlinear function.
P_3	RV2	2-in. general-purpose precision pot with standard ½ per cent linear output.

*Generates nonlinear functions with shunting resistors between the fixed terminals and three equally-spaced taps, Figure 4. This figure shows that optimum adjustment of shunt resistors to give equal plus and minus errors permits pot to generate nonlinear curve. For greater accuracy slight intrinsic nonlinearity can be designed into the pot.

FIG. 4. Nonlinear potentiometer curve obtained from tap-shunted pot. Matches thermistor characteristics by a series of straight lines.



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2. *CHARACTERISTICS OF PRECISION SERVO COMPUTER POTENTIOMETERS*, D. C. Duncan, presented at AIEE Conference on Feedback Control Systems, Atlantic City, N. J., December 1951.
3. *DEVELOPMENT OF POTENTIOMETERS*, L. E. Packard, presented at AIEE meeting, Binghamton, N. Y., April 1952.
4. *TIC POTENTIOMETER HANDBOOK*, published by Technology Instrument Corp., January 1954.
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7. *HERE'S A SHORTCUT IN COMPENSATING POT LOADING ERRORS*, J. Gilbert, "Control Engineering", February and March 1955.
8. *REDUCING POTENTIOMETER LOADING ERROR*, F. E. Dole, "Review of Scientific Instruments", May 1947.

SPECIFICATIONS AND STANDARDS

1. Military Specification JAN-R-19, "Variable Wire-Wound Resistors (Low Operating Temperature)".
2. Military Specification MIL-R-12934 (SigC), "Precision Wire-Wound, Variable Resistors".
3. Radio-Electronics-Television Manufacturers Association Standard REC-121-B, "Variable Control Resistors".

Cascade Control Systems

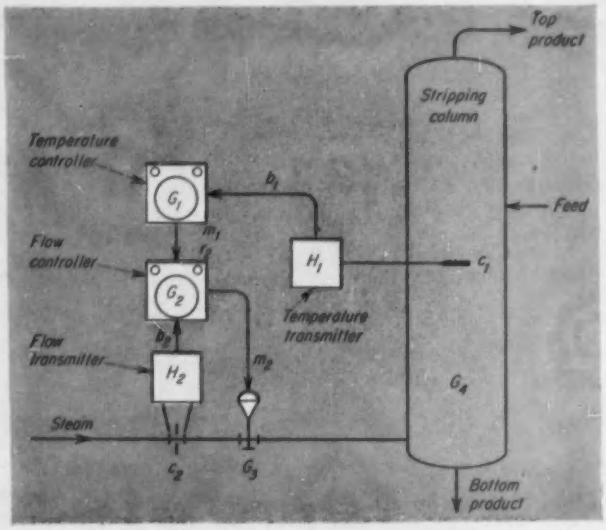


FIG. 1. Typical cascade control system on a stripping column. This system needs one control loop to control the flow of steam and another to control the temperature in the column. But because the temperature in the column depends on the flow rate, the output of the temperature controller is used to adjust the set-point of the flow controller and thus keep the heat input under better control.

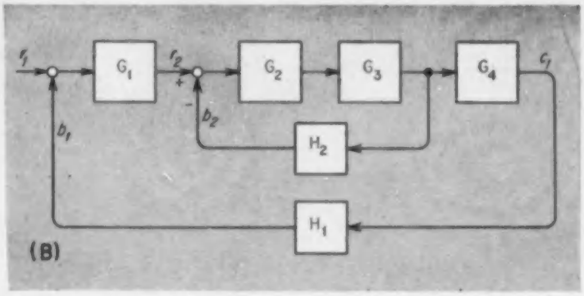
NORMAN W. GOLLIN, Taylor Instrument Cos.

THE GIST: Automatic control systems maintain the output, or controlled variable, at a constant value. The controller can have a variety of responses in it to provide the desired startup characteristics, stability, and speed of recovery after a disturbance. These points were covered by Zoss and Coon in previous articles on process control.

Proper choice of the control arrangement improves the performance of the control system. If this arrangement involves the adjustment of the set-point of the controller in a control loop by means of another measured variable, it is called CASCADE CONTROL. The type of cascade control system considered here is one where the two measured variables are related though the process. By block diagrams and transfer functions of the system's elements, cascade control systems can be analyzed to show how much they improve control of the process.

Cascade control is a special arrangement in closed-loop control, in that the set-point of a controller controlling one variable is adjusted or modified by means of another measured variable. Many processes contain one or more variables that are related to the primary control variable. Better control of the primary variable can usually be obtained if one of these secondary variables is used to control the input to the process. The set-point of the related variable controller is then adjusted by the primary controller to form a multiple-loop cascade system.

As an example of multiple-loop cascade control consider the stripping column shown in Figure 1. Here, the heat input at the bottom of the column must be steady for best operation. The flow controller maintains a constant heat input to the column and forms the first control loop. However, the set-point of this flow controller cannot remain fixed, because the flow must be changed if the temperature in the column changes due to a fluctuation in feed. This calls for another controller and a second control loop that responds to changes in column temperature at point C_1. The output of this controller adjusts the set-point of the flow controller so that the flow rate increases with a falling column temperature. The temperature in the column, closely related to the quality of the product, is the measurement made in the primary control loop. The secondary loop comprises the flow-control loop. The temperature and flow are related through the transfer functions of the process.



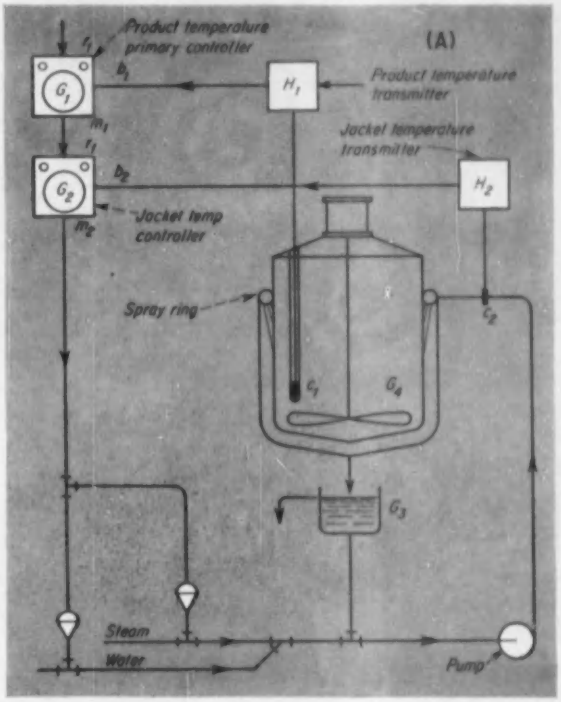


FIG. 2. Figure 2A, the jacketed kettle and its control arrangement. This is another example of multiple-loop cascade control. Figure 2B, the equivalent block diagram that aids analysis of system performance.

Figure 2A shows the equipment arrangement for cascade control of a jacketed kettle. Here, the internal kettle temperature, which is of primary importance, is measured and controlled by adjusting the set-point of the spray-water temperature controller. The equivalent block diagram in Figure 2B shows that this is a multiple (2) closed-loop cascade system. Thus, a two-loop cascade system consists simply of a primary closed loop and a secondary loop, but with automatic means for adjusting the secondary controller's set-point. Here again this view enables analysis of performance by the usual transfer-function methods.

ANALYZING CASCADE SYSTEMS

Multiple-loop cascade systems provide certain advantages not offered by single-loop systems. Analysis will show that multiple-loop cascade control:

- reduces the effect of disturbances
- increases the natural frequency of the system
- reduces the effective magnitude of some time constants

Other advantages, not detailed in this article:

- adjustment and control of the primary variable—impossible in some control systems without cascade control
- provision in the secondary-loop controller for high and low limit stops to prevent undesirable effects produced when the secondary variable exceeds these limits

The advantages of cascade control can best be shown by comparing the performance characteristics of a cascade system with those of a less complicated single-loop control system on the same process. Single-loop control on the stripping column shown in Figure 1 would have a single controller which responds to the temperature in the column and adjusts the steam-supply valve directly. Similarly, a controller actuated by the temperature measurement in the jacketed kettle shown in Figure 2A would adjust the control valves.

Single-Loop Control Systems

The block diagram for a single-loop control system is shown in Figure 3. To minimize unnecessary complications in the analysis, the process is considered as having two parts, each with a separate transfer function G_3 and G_4 which are noninteracting. Temperature transmitter H_1 measures the controlled variable c. r is the set-point for the controller G_1 and u is a disturbance introduced between the output of the controller and the input to the process. This disturbance could be a variation in the controlling material passing through the control valve. The set-point of the controller is adjusted for the desired value for c. This control system maintains the primary variable c at the set-point r.

The transfer function of this closed loop between set-point r and the controlled variable c describes their dynamic relationship and is:

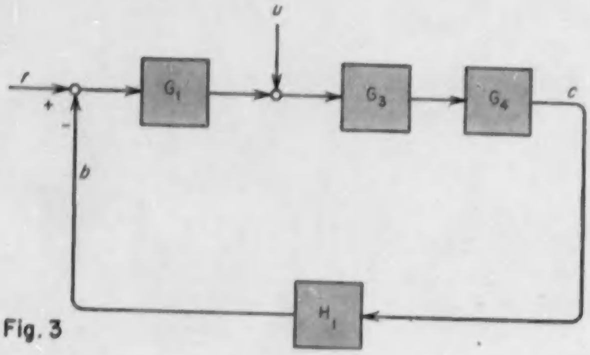


Fig. 3

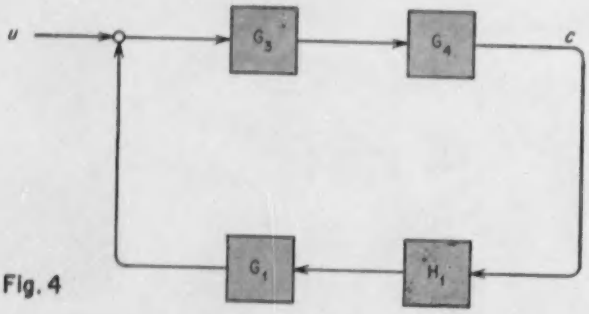


Fig. 4

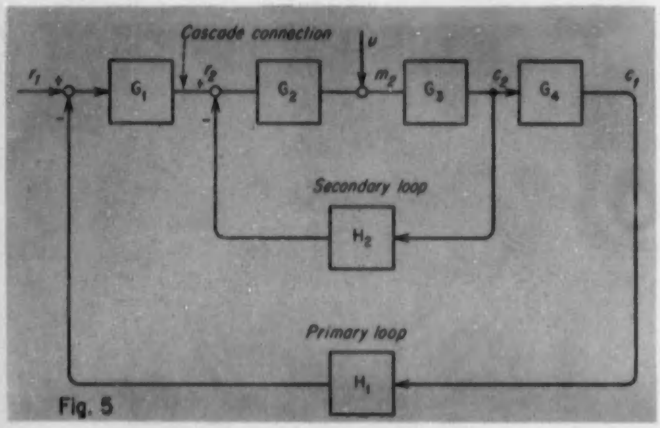


Fig. 5

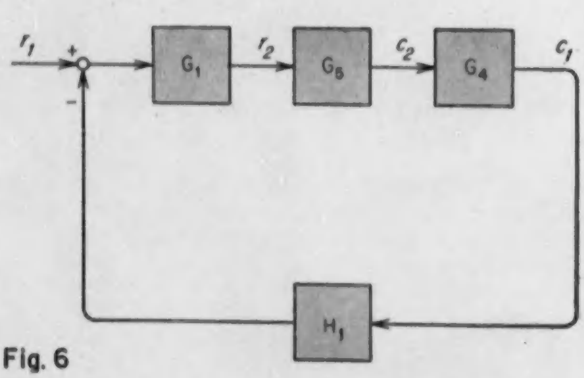


Fig. 6

$$\frac{\text{Output}}{\text{Input}} = \frac{c}{r} = \frac{\text{Feed Forward Transfer Function}}{1 + \text{Feed Forward} \times \text{Feed Back}}$$

$$= \frac{G_1G_3G_4}{1 + G_1G_3G_4H_1} = \frac{1}{H_1} \times \frac{G_1G_3G_4H_1}{1 + G_1G_3G_4H_1} \quad (1)$$

Now consider a disturbance u between the output of the controller and the input to the process element G_3. The transfer function for the closed loop where u is the input will describe the effect of the disturbance on the primary variable c. Rearrangement of Figure 3 into Figure 4 simplifies this analysis, and the resulting transfer function in this case is:

$$\frac{c}{u} = \frac{1}{G_1H_1} \times \frac{G_1G_3G_4H_1}{1 + G_1G_3G_4H_1} \quad (2)$$

The set-point reference to disturbance ratio,

$$\frac{c/r}{c/u} = G_1 \quad (3)$$

shows that single-loop control favors maintaining the controlled variable at the set-point, following a disturbance at the place indicated, by a factor G_1. The extent to which disturbances are rejected by this system will depend on the proportional gain setting of the controller G_1 when it is adjusted for optimum stability.

The time required for the system to recover after a disturbance varies inversely with the natural frequency of oscillation of the system. If we assume the following transfer functions:

$$G_1 = k_1$$

$$G_3 = \frac{k_3}{1 + T_3p}$$

$$G_4 = \frac{k_4}{1 + T_4p}$$

$$H_1 = k_{11}$$

then the open-loop zero-frequency gain

$$k_1k_3k_4k_{11} = K > 1$$

The undamped natural frequency of the single-loop control system is:

$$f_n(\text{single-loop}) = \frac{1}{4\pi D} \times \frac{T_3 + T_4}{T_3T_4} \quad (4)$$

when the system is adjusted to have a damping factor D.

TERMINOLOGY

r = set-point for controller in single control loop
c = controlled variable in single control loop
r_1 = set-point for primary control loop
c_1 = controlled variable for primary control loop
r_2 = set-point for secondary control loop
c_2 = secondary controlled variable
u = disturbance
G_1 = primary controller
G_2 = secondary controller
G_3 = part of process
G_4 = part of process
H_1 = primary variable measurement
H_2 = secondary variable measurement
p = frequency variable, $2\pi f$
T = time constant
K = open-loop zero-frequency gain

Multiple-Loop Cascade Systems

The primary objective in using multiple-loop cascade control is better control than is available from a single-loop control system. Figure 5 shows the typical block diagram of the multiple (2) loop cascade system. The reasons for using multiple (2) loop cascade control rather than single-loop control are to obtain:

- a closed loop, c/r zero-frequency gain closer to unity
- a higher natural frequency
- smaller effects of disturbances.

To find the closed-loop transfer function c_1/r_1 for the system in Figure 5, the transfer function for the secondary closed loop must be found first and then replaced in Figure 5 as a single block. Since the secondary closed loop is of the same form as the single closed loop of Figure 3, its transfer function will be similar, and in this case becomes

$$\frac{c_2}{r_2} = \frac{1}{H_2} \times \frac{G_2G_3H_2}{1 + G_2G_3H_2} = G_5 \qquad (5)$$

Therefore Figure 5 can be redrawn, as in Figure 6, to show the substitution of the secondary closed loop by its equivalent block, G_5.

The transfer function of the complete system that can now be found from Figure 6 describes how closely the controlled variable c_1 holds to the set-point r_1. Thus:

$$\frac{c_1}{r_1} = \frac{1}{H_1} \times \frac{G_1G_5G_4H_1}{1 + G_1G_5G_4H_1} \qquad (6)$$

Replacing the secondary loop by a single block is permissible only if the secondary control loop is stable by itself when disconnected from the primary loop. It is possible in multiple-loop cascade control to obtain stability even though the settings of the secondary-loop controller are so adjusted that the secondary-loop itself is unstable. But if the cascade connection is broken, as it must be in industrial process control systems when manual control is required for startup and emergencies, then unstable performance within the process results, because only the secondary loop controls the output variable. This is unacceptable for plant operation.

The transfer function of controlled variable to disturbance can be found by rearranging Figure 5 to that of Figure 7, which shows the disturbance u as the input. This block diagram contains, again, a primary and a secondary loop, which means the secondary loop can be replaced by a single block by finding its equivalent transfer function, G_6. In this case G_6 equals G_5/G_2; it is substituted into Figure 7 to yield Figure 8, which aids in finding the required transfer function in terms of the original blocks:

$$\frac{c_1}{u} = \frac{1}{G_1G_2H_1} \times \frac{G_1G_5G_4H_1}{1 + G_1G_5G_4H_1} \qquad (7)$$

The command to disturbance ratio is

$$\frac{c_1/r_1}{c_1/u} = G_1G_2 \qquad (8)$$

The undamped natural frequency

$$f_n\ (\text{cascade}) = \frac{1}{4\pi D} \times \frac{T_3 + KT_4}{T_3T_4} \qquad (9)$$

shows that cascade control favors holding the controlled variable at the set-point, following a disturbance at the place indicated, by a factor $G_1\ G_2$. The proportional gain setting in the controller G_1, used in the multiple system, is not the same value as that used in the single-loop case. But since $G_1\ G_2$ is larger than the G_1 in the single-loop system, the variable c_1 responds less to a given disturbance when controlled by the multiple-loop system.

Raises Natural Frequency

A high natural frequency of oscillation following a disturbance speeds recovery of a stable system back to its set-point. Under practical stability requirements this takes about 2½ to 3 cycles. Thus a control system with a high natural frequency recovers in shorter time.

When a process can be represented by two major time constants, the relative increase in natural frequency of oscillation due to cascade control over that of single-loop control can be computed from the following relationship:

$$\frac{f_n\ (\text{cascade})}{f_n\ (\text{single loop})} = \frac{1 + KT_4/T_3}{1 + T_4/T_3} \qquad (10)$$

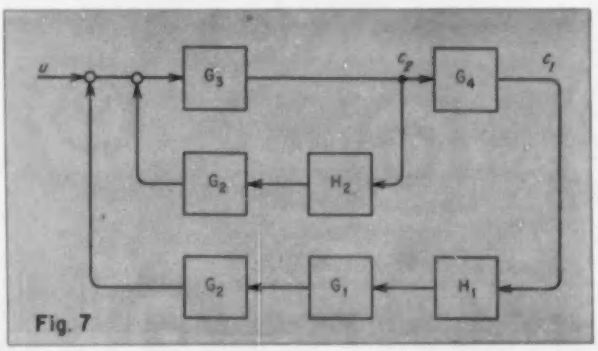


Fig. 7

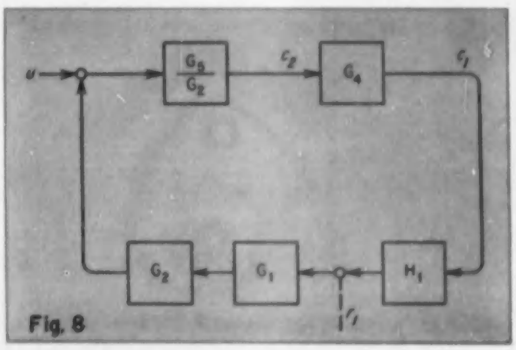


Fig. 8

RAISING NATURAL FREQUENCY SPEEDS RECOVERY

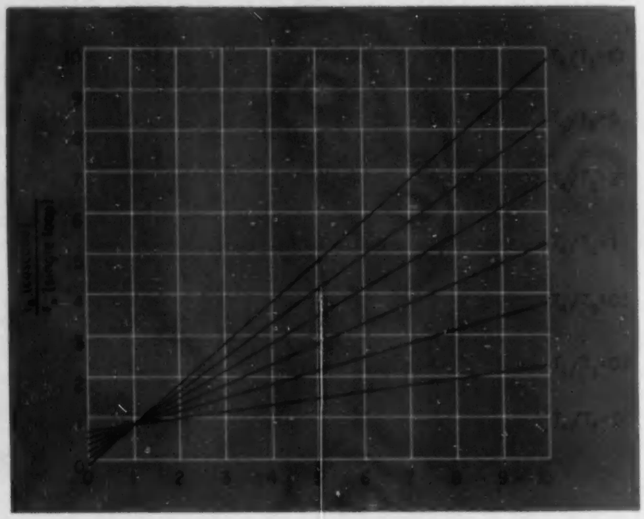


FIG. 9. For a two-time-constant system represented by T_3 (in the secondary loop) and T_4, and by a gain K in the secondary open loop, the ratio of natural frequencies between a cascade system and a single-loop increases as T_3 decreases and the gain, K, increases.

where

T_4/T_3 = ratio of time constants in a two-time-constant process and where, in multiple-loop control, T_3 is in the secondary loop.

K = gain at zero frequency of open secondary loop in the multiple-loop system and is considerably larger than unity.

Both systems are adjusted to have the same damping factor.

Figure 9 shows the plot of the above equation. Note that the natural frequency of the multiple-loop system increases over that of the single-loop system when the gain of the secondary open loop increases, and when the time constant in the secondary loop is small compared with the other time constant in the system.

Reduces Time Constant

Because the time constants in the transfer functions for the various elements in a control system affect the natural frequency of the system, it is difficult to claim an increase in natural frequency and a reduction in effective time constant as two independent advantages of a multiple-loop cascade-control system.

However, closing the control loop around an element effectively reduces its time constant. As an example of this, reconsider the secondary loop of Figure 5 that was replaced by its equivalent single block G_8 in the primary loop. Suppose the element G_3 in the secondary loop has a transfer function $k_3/l + T_3p$), and the zero-frequency secondary-open-loop gain, K, is somewhat greater than unity. The secondary closed-loop transfer function now is

$$\frac{c_3}{r_3} = \frac{1}{H_3} \times \frac{1}{1 + \dfrac{T_3p}{K}} = \frac{k_5}{1 + T_5p} = G_8 \qquad (11)$$

Thus closing the loop around the element reduces the time constant by a factor equal to the zero-frequency open-loop gain; that is, T_5 equals T_3/K.

Conclusion

Cascade-control systems can provide better control than is obtainable with single-loop systems.

1. The effect of a disturbance in the process is least when it is included in the secondary loop.
2. When attempting to improve the performance of a control system, one recognized rule is to reduce the size of the second largest lag in the system. When considering a cascade-control system, attempt to close the secondary loop around the second largest lag. This has the affect of reducing the lag to a smaller value.

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NEW

MICROAMMETER
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RECORDER
PERFORMS 6
ESSENTIAL FUNCTIONS

- ★ **Measures low-level dc signals with calibration accuracy within 0.5%, and sensitivity within 0.2% of span.**
- ★ **Records on 3" continuous strip chart or IBM-type card chart, with linear coordinates.**
- ★ **Positions recording pen with force many thousand times greater than usual direct-deflection electrical movements.**
- ★ **Operates on force-balance principle compensating for ambient conditions, changes in power supply and components.**
- ★ **Gives high-speed recording — up to 0.05 seconds for 63% of fullscale changes.**
- ★ **Provides span and zero adjustments for ease of calibration and zero suppression in the field, without special equipment.**

The new 'American-Microsen' Series 130 Recorder is a highly sensitive microammeter or millivoltmeter that gives positive, accurate electrical measurement and rugged, maintenance-free service. Yet the unit costs less than other recorders for the same purpose.

Heart of the Series 130 Recorder is the "Microsen" balance that converts low-level dc input signals into powerful output current to drive the recording pen. Pen position is fed back to the input. Consequently, the recording unit is force-balanced in precise relationship with the input signal. Power is ample to operate alarm contacts, which are available.

SPECIFICATIONS

POWER SUPPLY: 115 volts, 60 cycles. **POWER REQUIREMENT:** 9 watts

INPUT RANGES: Voltage – 0-20 millivolts to 0-100 volts dc. **Current** – 0-200 microamperes to 0-100 milliamperes dc. **Input Sensitivity** – 6700 ohms per volt.

ACCURACY: ± 0.5% of span. **SENSITIVITY:** ± 0.2% of span. **REPEATABILITY:** ± 0.25% of span.

EFFECT OF SUPPLY VOLTAGE: Less than 0.5% error 90-130 volts.

EFFECT OF AMBIENT TEMPERATURE: Less than 0.5% error 50° to 100° F., and less than 1% to 130° F.

RESPONSE TIME: Fast Speed – 0.2 seconds standard for 63% of fullscale input change; up to 0.05 seconds for 63% on special order. **Slow Speed** – approximately 4 times fast speed setting.

SHOCK RESISTANCE: Withstands shock up to 30 times gravity.

CHART SPEEDS: Strip Chart – 1" per hr., standard; 3" or 6" per hr. available. **Card Chart** – 1 rotation per day, standard.

SPAN ADJUSTMENT: ± 10% of span. **ZERO ADJUSTMENT:** ± 100% of span.

PRICE: $250.00 consumer net for standard models.

Write for Bulletin MG10

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INDUSTRIAL CONTROLS DIVISION, STRATFORD, CONNECTICUT

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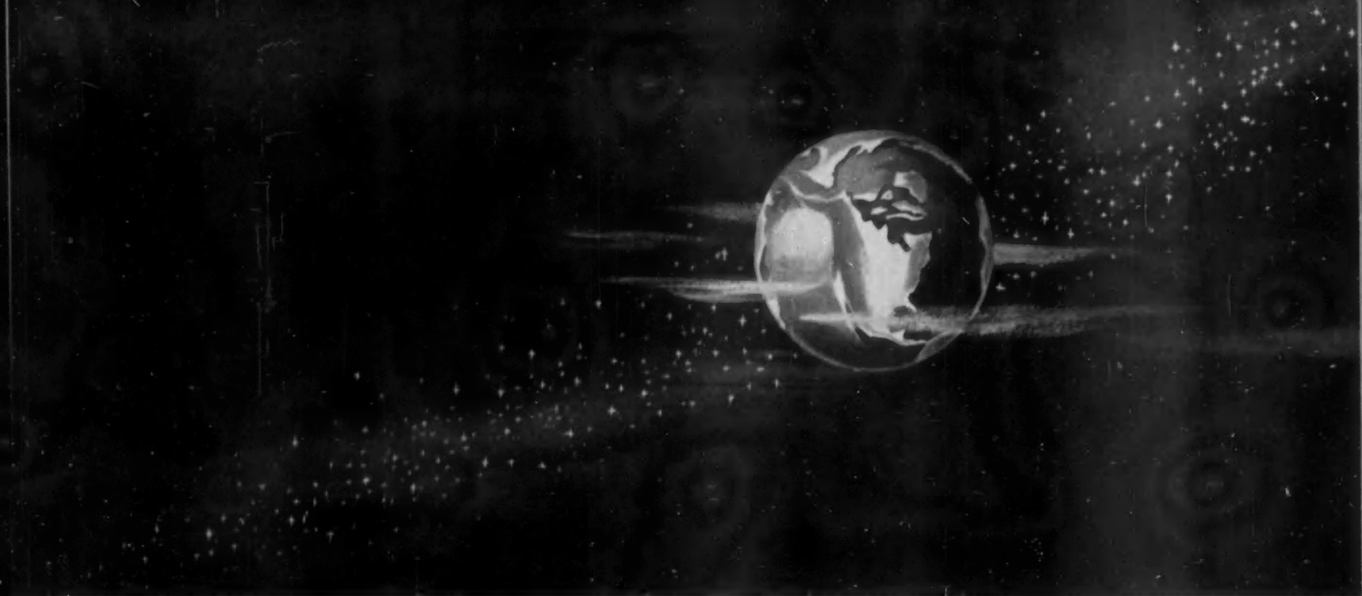

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Let's Look at the Available Business-Data Processors

The possibility of making a selection from a range of suitable business-data processing systems is just now approaching. At present, you can almost count on both hands all of the electronic data-processing systems that are successfully achieving the purposes for which they were obtained. But this situation is changing rapidly. Papers describing successful applications are beginning to appear at computer and management society meetings. Some data processors intended for business problems are actually handling more scientific calculations; others have proven unsuccessful, either because of incorrect application, insufficient capacity, or lack of user acceptance. Many thousands of words have been devoted to systems that are in the planning stage, or at most have a very few field installations, the latter usually still being programmed or debugged.

Author Gibbons steps into this maelstrom to bring you up-to-date on the currently available and planned data processors. He lists the characteristics of these systems, and points out those characteristics that are important in business applications. The availability of electronic equipment is affecting the organization of business operations, and, in turn, the demands of certain business operations are steering the design of current and future processors. Gibbons discusses areas affected by this inverse "systems" approach, where both process organization and processor design must give a little to yield optimum results. The flow diagram and detailed program steps for an integrated inventory control system are included to give a sense of reality.

JAMES GIBBONS
Price Waterhouse & Co.

Today, with systems specialists analyzing and evaluating data-processing equipment for a myriad of specific clerical applications in various companies, and with the equipment itself ranging from an abacus to a NORC, it is important that these devices be defined and classified. Fortunately, definitions have recently been provided, which, if not scientifically precise, at least bear the unmistakable stamp of authority. In a recent court finding[1] a *tabulating system* is defined as "... any group of machines capable of entering, converting, receiving, classifying, computing, and recording alphabetic and/or numeric accounting and/or statistical data by means of tabulating cards, and in which tabulating cards are used for storing data and communicating it within the system ...". On the other hand, an *electronic data-processing system* "... shall mean any machine or group of automatically intercommunicating machine units capable of entering, receiving, storing, classifying, computing and/or recording alphabetic and/or numeric accounting and/or statistical data without intermediate use of tabulating cards, and which system includes one or more central data-processing facilities and one or more storage facilities and has either:

1. the ability to receive and retain in the storage facilities at least some of the instructions for the data-processing operations required, or
2. means, in association with storage, inherently capable of receiving and utilizing the alphabetic and/or numeric representation of either the location or the identifying name or number of data in storage to control access to such data, or
3. storage capacity of 1,000 or more alphabetic and/or decimal numeric characters or the equivalent thereof ...".

These definitions imply several things. First, any system depending

TABLE 1 CHARACTERISTICS OF

MANUFACTURER	Model	Availability	Lease or Purchase	Price Class*	CENTRAL UNIT Capacity in Characters	A—Alphanumerical N—Numerical	Total Number of Stored Instructions
BURROUGHS CORP.	E 101	Current	L/P	L	2,640	N	External
DATAMATIC CORP.	DATAmatic 1000	Planned	L/P	H	24,000	N	2,000
ELECTRODATA CORP.	Datatron	Current	L/P	M	40,800	N	4,080
ELECTRONICS CORP. OF AMERICA	Magnefile-F	Current	L	L	180,000	N	Fixed, 10 Keyboard entries
INTERNATIONAL BUSINESS MACHINES CORP.	650	Current	**L/P	M	20,000	N	2,000
	702	Superseded	**L/P	H	10-20,000	A	2,000 — 4,000
	705	Current	**L/P	H	20-40,000	A	4,000 — 8,000
LABORATORY FOR ELECTRONICS, INC.	DIANA	Planned	P	M	10,000 + 54,000	A	
MARCHANT RESEARCH, INC.	MINIAC	Current	P	M	4,096 × 10	N	8,192
MONROBOT CORP.	Monrobot-MV	Planned	P	M	4,000	N	400
MOUNTAIN SYSTEMS, INC.	Modac-404	Special order	P	M	120,000	N	Fixed Internal
NATIONAL CASH REGISTER CO.	304	Details not available		M			
RADIO CORP. OF AMERICA	BIZMAC	Current	P	H	4,096 + 32,736	A	4,092
REMINGTON RAND, DIVISION OF SPERRY RAND	UNIVAC File Computer	Current	L/P	M	10,880	A	990
	UNIVAC I	Current	L/P	H	12,000	A	2,000
	UNIVAC II	Planned	L/P	H	24-120,000	A	4,000 — 10,000
TELEREGISTER CORP.	Reservisor	Special order	P	M	45,000	N	Fixed Internal
UNDERWOOD CORP.	Elecom 125	Current	L/P	M	10-100,000	N	1,000 — 10,000
	Elecom 50	Current	L/P	L	500	N	External

*Price Code:
L — Under $100,000
M — $100,000 to $1,000,000
H — Over $1,000,000

**Available for sale after Jan. 1957

BUSINESS-DATA PROCESSORS

			MAGNETIC TAPE UNITS					
Instruction Type, Address	Storage Medium	Access Time, Minimum, millisec	Maximum No. of Units, On-Line	Forward Speed, in. per sec	Rewind Speed, in. per sec	Recording Density, char. per in.	Recording Mode, FW—Fixed word VW—Variable word FB—Fixed block VB—Variable block
1	Drum	1.67	None				FW
3	Core	0.010	200	100	100	156 (31 channels)	FW, FB
1	Drum	0.85	10	60	159	100	FW, FB
1	Drum	—	None				
1+1	Drum	0.098	6	75	500	200	FW, VB
1	CRT, cores	0.023	100	75	500	200	FW, VB
1	Core	0.017	100	75	500	200	FW, VB
1	Core + drum	0.044	1				
1	Drum	1.25	Any number	40	400	32	
4	Drum	16.0					
1	Drum	50.0	None				
	Core						VW, VB
3	Core + drum	0.02, 5.2	Any number	80	80	125	VW, VB
3	Drum	5.0	24	60	60	100	FW, VB
1	Delay line	0.040	10	100	100	128	FW, FB
1	Core	0.040	10	100	100	200	FW, FB
1	Drum	50.0	None				
2	Drum	1.7	Any number	20		100	FW, VB
	Drum	50	None				

TABLE 1 (continued)

MODEL	PERIPHERAL EQUIPMENT: Punched Cards: Input: Speed, Cards per min	Punched Cards: Input: On-Line	Punched Cards: Input: Off-Line	Punched Cards: Output: Speed, Cards per min	Punched Cards: Output: On-Line	Punched Cards: Output: Off-Line	Paper Tape: Input: Speed, char. per sec	Paper Tape: Input: On-Line	Paper Tape: Input: Off-Line	Paper Tape: Output: Speed, char. per sec	Paper Tape: Output: On-Line	Paper Tape: Output: Off-Line	High-Speed Printer: Lines per min	High-Speed Printer: On-Line	High-Speed Printer: Off-Line
E 101								×			×				
DATAmatic 1000	900		×	100		×							900		×
Datatron	240	×		100	×		500	×		60	×		150	×	
Magnefile-F															
650	200	×		100	×				×			×	150	×	×
702	250	×	×	100	×	×			×			×	1,000	×	×
705	250	×	×	100	×	×			×			×	1,000	×	×
DIANA							200	×		60	×		150	×	
MINIAC							10	×		10	×				
Monrobot-MV		×					60	×		10	×				
Modac-404	240	×					200	×		20	×				
304															
BIZMAC	400		×				200		×	20		×	600		
UNIVAC File Computer	200	×					200	×		60	×				
UNIVAC I	240		×	100		×			×			×	600		×
UNIVAC II	240		×	100		×			×	60		×	600		×
Reservisor															
Elecom 125	240	×		100	×		400	×			×		300	×	
Elecom 50															

OTHER FEATURES
Plugboard programming
10 tapes searching simultaneously at up to 600,000 char. per sec
10 multiple tape bins available; provide 200,000,000 char. in tape rapid access storage
Typewriter output, special keyboard input
High-speed storage, 60 word core memory
Magnetic drum auxiliary memory
Tape Record Coordinator, Tape Data Selector, magnetic drum auxiliary memory
Bulk drum storage up to 71,400,000 char.
Tape capsules prepared by special typewriter are basic input and output
Tape sorter, interrogation unit, photographic output printer
Multiple drum memory up to 1,800,000 char.
Simultaneous read, write and compute; duplicate circuitry; tape verifier
Same as UNIVAC I
Special keyboard—display units for input-output
File processor (sorter and collator); fixed program and 60 in. per sec tape speed
Drum used as series of accumulator registers; programs stored on embossed plastic tape

on tabulating cards for data storage and communication is not an electronic data-processing system. Second, an electronic data-processing system consists of automatically intercommunicating machines. And third, an electronic data-processing system processes accounting and statistical data.

The attributes of business-data processing have already been assessed in this series and in other publications[2,3]. In review, those business operations that can best be handled by electronic data-processing systems are characterized by:

- ►large volumes of information, either active or in file form.
- ►considerable editing and transformation of this information
- ►relatively heavy computation or logical manipulation
- ►more or less fixed scheduling of processing operations to meet cyclic demands.

Conversely, data-processing equipment intended for business applications must have the ability to cope with these characteristics. Table I lists the commercially available data processors and those of their capabilities that are important in data-processing applications.

From the user's viewpoint, an investment in data-processing equipment must lead to economic benefits. Therefore it should be possible to establish a figure or price range that represents the amount available for acquiring a new data-processing tool. First, determine the cost of present operations considered to be within the scope of the data-processing application. Then estimate the anticipated cost (with present methods and equipment) of performing additional desirable functions and of providing for the future growth of present operations. The sum of these two costs represents the total amount available for replacement (either wholly or partially). However, this figure must be reduced by some portion of the cost of planning and installing the new system, and converting from the present procedure. The portion depends on the individual technique of handling the expenses of a methods and procedures organization, and of accounting for physical modification to plant and equipment.

But this reduced figure still includes the anticipated savings, which can be estimated by evaluating various types of equipment and methods. Deducting the anticipated dollar savings leaves a remainder representing a price tag or price range for a new data-processing system. The specific equipment can then be chosen on a sound financial basis, and the potential user need not be beguiled by the power of the larger systems or the price of the smaller ones.

Thus, the first basis for classifying data-processors is price. Table I gives no exact figures, since the price of complete systems varies with the number of units and the peripheral equipment. Rather, the table classifies the data processors in one of three price ranges. Generally speaking, the lower-priced units are the slower and less flexible. The "high" category includes equipment using magnetic-core storage (usually over 10,000 alphabetic characters) with considerable flexibility in handling various input-output units. These are: DATAmatic 1000, IBM 702 and 705, RCA BIZMAC, and Sperry Rand UNIVAC I and II. The "medium" range includes the large group of drum storage machines with magnetic tape units.

While the primary classification is by price, this still does not throw any real light on the unique features that give various units a competitive edge. These features include:

1. Internal Storage Capacity (not tape)

High—DIANA System
71,400,000 alphanumeric char.
—UNIVAC File Computer
1,800,000 alphanumeric char.

Medium—UNIVAC II (10,000 words)
120,000 alphanumeric char.
—Datatron
40,800 numeric char.
—IBM 705
40,000 alphanumeric char.

Low—Elecom 50
1,325 numeric char.

2. On Line Operation of Input-Output Units

IBM 702 and 705
Up to 100 tape units; additional drums, and card punches and readers.

UNIVAC File Computer
24 input-output devices.

3. Variable Record Length (tape recording)

RCA BIZMAC
IBM 702 and 705

4. Variable Word Length

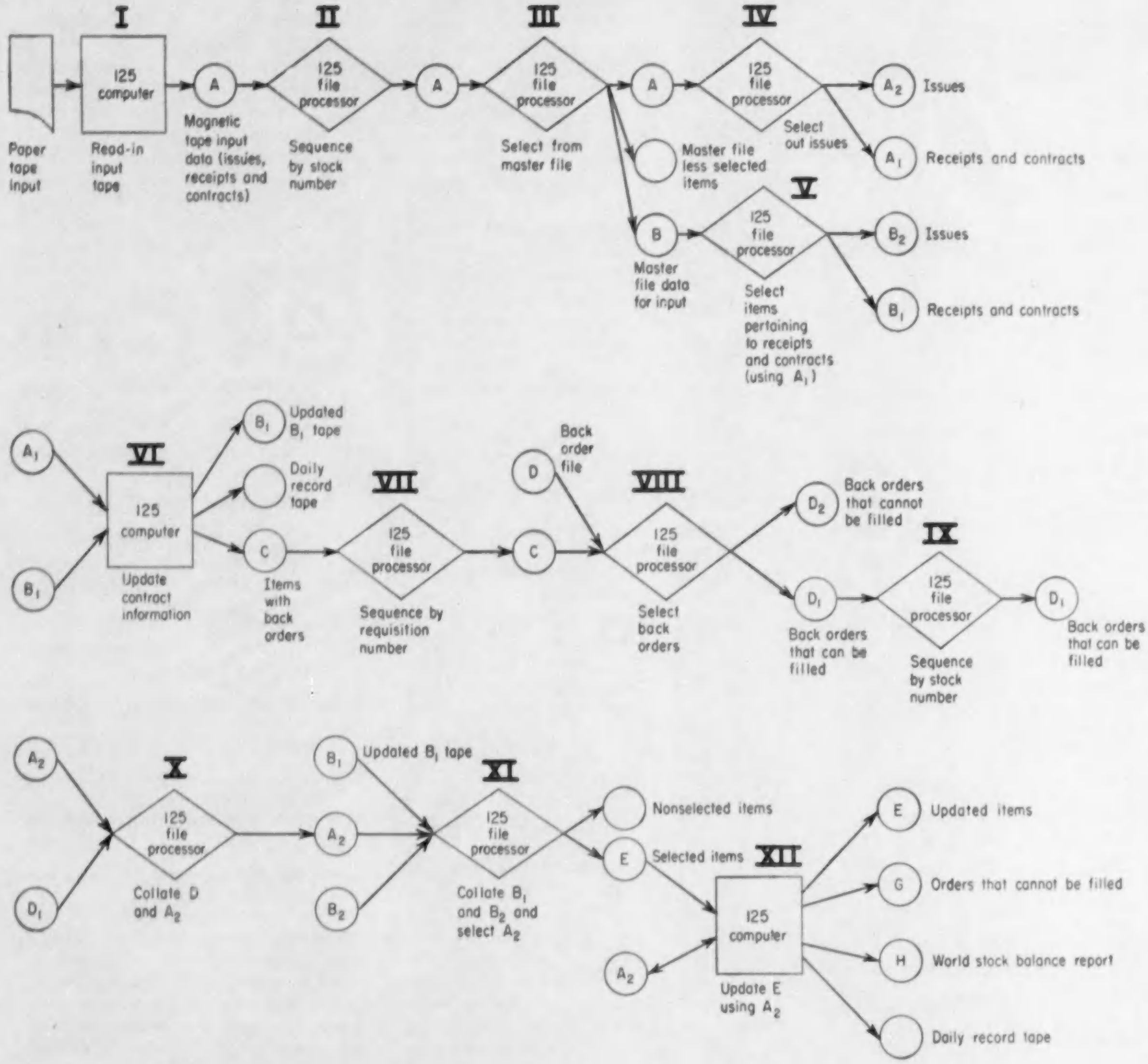
RCA BIZMAC

There are other important system characteristics, as shown in Table I, that must also be evaluated in terms of specific applications. Typical items are the various instruction repertoires and the address systems. For example, one system (BIZMAC) does not provide a divide instruction, yet the machine can be programmed to do division by repetitive subtraction. The designers of this equipment felt that this was a realistic approach in terms of reduced equipment costs, due to the infrequent use of division instructions in business problems. Checking systems are another valuable feature that can be accomplished in a number of different ways. While some systems offer more checking features than others, the value and costs of the checks must be measured in terms of error probabilities and risks.

Having looked at most of the available systems, it is now possible to consider these systems in the light of the desirable features of the three

FIG. 1 THE DETAILS OF AN INTEGRATED

THE FLOW DIAGRAM



THE BASIC TAPE FILES

1. MASTER INVENTORY FILE: 5,000 items sequenced by stock number, four blocks per item, on 36,000 in. of tape.
   a. Designator block: stock no., etc.
   b. Trailer block 1: packing information, etc.
   c. Trailer block 2: back orders, amounts, requisition no., etc.
   d. Trailer block 3: contract data, date due in, amount, etc.
2. BACK ORDER FILE, sequenced by requisition number. 500 back orders at 220 digits each.
3. ADDRESS FILE, names and addresses, shipping instructions, etc.
4. CONTRACT FILE.

THE INPUT DATA

1. ISSUES: 400 items per day, 220 digits each.
2. RECEIPTS: 50 items per day, 100 digits each.
3. CONTRACT INFORMATION: 50 items per day, 100 digits each.

SUMMARY OF DAILY OPERATING TIME

OPERATION	COMPUTER	FILE PROCESSOR
I	7.1 min	
II		3.5 min
III		14.4 min
IV		0.5 min
V		1.5 min
VI	3.1 min	
VII		0.1 min
VIII		0.5 min
IX		0.3 min
X		0.4 min
XI		1.8 min
XII	16.3 min	
	Total 26.5 min	23.0 min

INVENTORY CONTROL SYSTEM

THE PROGRAM STEPS AND TIME PER STEP

I. READ PAPER TAPE INTO COMPUTER, AND PREPARE INPUT (MAGNETIC) TAPE FOR: 1. ISSUES, 2. RECEIPTS, AND 3. CONTRACTS:

a. Read in 98,000 characters:

$$\frac{98{,}000 \text{ characters}}{400 \text{ characters per sec}} = 245 \text{ sec}$$

b. Set up designator blocks:
(500 items) × (30 instructions per item) = 15,000 instructions

$$\frac{15{,}000 \text{ instructions}}{150 \text{ instructions per sec}} = 100 \text{ sec}$$

c. Read out onto magnetic tape (tape A):

$$\frac{980 \text{ in.}}{20 \text{ in. per sec}} = 49 \text{ sec}$$

d. Start-stop time:
(500 blocks) × (0.06 sec per block) = 30 sec

Total time = 7.1 min

II. SEQUENCE INPUT TAPE BY STOCK NUMBER ON THE FILE PROCESSOR:

a. Read or write time:
500 items require 8 passes (since log base 2 of 500 equals approximately 9)

$$\frac{(980 \text{ in.}) \times (8 \text{ passes})}{60 \text{ in. per sec}} = 131 \text{ sec}$$

b. Start-stop time:
(8 passes) × (500 blocks) × (0.02 sec per block) = 80 sec

Total time = 3.5 min

III. SELECT ITEMS FROM MASTER INVENTORY TAPE:

a. Read or write time:

$$\frac{26{,}000 + 980}{60 \text{ in. per sec}} = 450 \text{ sec}$$

b. Start-stop time:
(20,000 + 500 blocks) × (0.02 sec per block) = 410 sec

Total time = 14.4 min

IV. SELECT RECEIPTS AND CONTRACTS FROM INPUT TAPE:

a. Read or write time:

$$\frac{980 \text{ in.}}{60 \text{ in. per sec}} = 16 \text{ sec}$$

b. Start-stop time:
(500 blocks) × (0.02 sec per block) = 10 sec

Total time = 0.5 min

V. SELECT ITEMS ON (SELECTED) MASTER INVENTORY TAPE TO BE UPDATED BY RECEIPTS AND CONTRACTS ON INPUT TAPE:

a. Read or write time:
Tape B = 500 (out of 5,000) items = 2,600 in.
Tape A_1 = 100 items = 100 in.

$$\frac{2{,}600 + 100}{60 \text{ in. per sec}} = 45 \text{ sec}$$

b. Start-stop time:
(2,100 blocks) × 0.02 = 42 sec

Total time = 1.5 min

VI. UPDATE ITEMS WITH RECEIPTS AND CONTRACT INFORMATION:

a. Read time:

$$\text{Tape } B_1 = 100 \text{ items} = \frac{2{,}600}{5} = 520 \text{ in.}$$

Tape A_1 = 100 in.

$$\frac{520 + 100}{20 \text{ in. per sec}} = 31 \text{ sec}$$

b. Start-stop time (input):
(100 × 4) + 100 = 500 blocks
500 blocks × 0.06 = 30 sec

c. Computing time:
50 instructions per item
100 items × 50 = 5,000 instructions

$$\frac{5{,}000}{150 \text{ instructions per sec}} = 33 \text{ sec}$$

d. Printing time (IBM 407):
100 items = 100 lines

$$\frac{100 \text{ lines}}{150 \text{ lines per min}} = 40 \text{ sec}$$

e. Write updated master inventory tape B_1 and write back order tape C:
Assume: 1 back order per item.
50 back orders × 20 digits each = 1,000 digits
Therefore: Tape C = 10 in. of tape
Tape B_1 (updated) = 520 in.

$$\frac{520 + 10}{20 \text{ in. per sec}} = 27 \text{ sec}$$

f. Start-stop time (output):
(100 × 4) + 50 = 450 blocks
450 × 0.06 sec per block = 27 sec

Total time = 3.1 min

VII. SEQUENCE ITEMS WITH BACK ORDERS BY REQUISITION NUMBER:

a. Read or write time:
50 items require 5 passes (log base 2 of 50 equals approximately 6)

$$\frac{10 \text{ in.} \times 5 \text{ passes}}{60 \text{ in. per sec}} = 1 \text{ sec}$$

b. Start-stop time:
5 passes × 50 items × 0.02 = 5 sec

Total time = 6 sec

VIII. SELECT BACK ORDERS THAT CAN BE FILLED FROM BACK ORDER FILE:

a. Read or write time:
500 back orders = 110,000 digits
= 1,100 in. tape
Tape C (used for selecting) = 10 in.

$$\frac{1{,}110 \text{ in.}}{60 \text{ in. per sec}} = 19 \text{ sec}$$

b. Start-stop time:
(500 + 50) × 0.02 = 11 sec

Total time = 0.5 min

IX. SEQUENCE BACK ORDERS BY STOCK NUMBER:

a. Read or write time:

$$50 \text{ items} = \frac{1{,}100}{10} = 110 \text{ in.}$$

50 items require 5 passes.

$$\frac{110 \times 5}{60 \text{ in. per sec}} = 9 \text{ sec}$$

b. Start-stop time:
50 × 5 passes × 0.02 = 5 sec

Total time = 14 sec

X. COLLATE ISSUES (INPUT) TAPE WITH BACK ORDERS THAT CAN BE FILLED:

a. Read or write time:
Tape A_2 = 880 in.
Tape D_1 = 110 in.

$$\frac{990}{60 \text{ in. per sec}} = 16.5 \text{ sec}$$

b. Start-stop time:
(400 + 50) × 0.02 = 9 sec

Total time = 26 se

XI. COLLATE MASTER INVENTORY ITEMS UPDATED BY RECEIPTS AND CONTRACTS WITH REST OF (SELECTED) MASTER INVENTORY ITEMS, AND SELECT (USING A_2) ITEMS TO BE AFFECTED BY ISSUES, AND BACK ORDERS THAT CAN BE FILLED:

a. Read or write time:
Tape B_1 = 520 in. (receipts and contracts)
Tape B_2 = 2,080 in.
Tape A_2 = 999 in. (issues and back orders)

Total = 3,599 in.

$$\frac{3{,}599}{60 \text{ in. per sec}} = 60 \text{ sec}$$

b. Start-stop time:
Tape B_1 = 400 blocks
Tape B_2 = 1,600 blocks
Tape A_2 = 450 blocks

Total = 2,450 blocks
2,450 × 0.02 sec. per block = 49 sec

Total time = 1.8 min

XII. UPDATE MASTER INVENTORY TAPE USING INPUT ISSUES TAPE:

a. Read time:
Tape E = 2,340 in.
Tape A_2 = 990 in.

Total = 3,330 in.

$$\frac{3{,}330}{20 \text{ in. per sec}} = 167 \text{ sec}$$

b. Start-stop time:
2,250 × 0.06 sec per block = 135 sec

c. Computing time:
50 instructions per item
450 items × 50 = 22,500 instructions

$$\frac{22{,}500}{150 \text{ instructions per sec}} = 150 \text{ sec}$$

d. Printing time:
450 items × 2 lines per item = 900 lines

$$\frac{900}{150 \text{ lines per min}} = 6 \text{ min}$$

e. Write update master inventory tape (E), orders that cannot be filled tape (G), and billing tape (A_2).
Note: billing tape must next be match-merged with name and address tape, etc.
Tape E = 2,340 in.
Tape G = 110 in. (50 back orders off and 50 back orders on)
Tape A_2 = 880 in.

Total = 3,330 in.

$$\frac{3{,}330}{20 \text{ in. per sec}} = 167 \text{ sec}$$

Total time = 16.3 min

primary portions of a business data processor: the central unit, magnetic tape units, and peripheral equipment.

The central unit

Business-data-processing applications usually require long programs, so that the size of the program storage medium is a good indication of the flexibility of the central unit. The column headed "Total Number of Stored Instructions" in Table I indicates the maximum number of instructions that could be stored if the entire memory was used for this purpose, though in practice this would never be done. The cost of the central unit varies almost directly with speed (access time). To minimize cost and still provide reasonable speed and storage capacity, some manufacturers use more than one type storage medium for program storage. In both the Laboratory for Electronics DIANA and the RCA BIZMAC, a limited-capacity high-speed core storage unit is supplemented by a large-capacity high-speed drum for program storage.

In the IBM 702 and 705, available magnetic drums can be used either to store instructions or tabular data. However, to be interpreted and executed, the instructions must be brought into the high-speed cathode-ray tube or core storage. There is no precise criterion for establishing a "reasonable" memory capacity for program storage in business-data processors. Burks, Goldstine, and von Neumann[7] established a reasonable size for scientific computers—about 1,000 to 4,000 words—but it appears that the more complex business programs require many thousands of words for any kind of integrated processing.

The address system has little effect on the quality of a system as a business-data processor. Single-address instructions may have an overall lower efficiency than three-address instructions, but the single-address system is slightly more flexible. Manufacturers' selection of an address mode is usually based on economic considerations.

Speed, of itself, has a fundamental effect on the efficiency of a central unit. This is particularly true where there are so many program steps that the input-output devices must wait for the central unit to complete a processing cycle before the next transaction can be processed. Then, total operating time becomes a function of central unit time.

Time sharing, or simultaneous operation of the input-output and computing facilities, offers the best arrangement for efficiently using all elements of a data processing system. This is usually accomplished with intermediate storage systems, or buffers, between the slower input-output units and the central unit. Then the central unit communicates only with the buffers, and there is no need for it to wait for the slower, mechanically controlled units to complete a processing cycle. Cost is a factor here, since buffer storage must be of the relatively costly high-speed type. In the UNIVACs I and II, two 60-word registers are provided for buffering. The IBM 705 system uses 1,024-character core memories in separate Tape Record Coordinators to permit simultaneous reading, writing, and computing.

Magnetic-tape units

Magnetic-tape units usually function as direct input-output, on line to the central unit. They are also used off line in the conversion of data to and from punched cards, paper tapes, and high-speed printers. Factors affecting tape efficiency include recording density, tape transport and rewind speed, and dead space for start-stop. Currently available units have tape densities of 200 characters per in., and tape speeds of 100 in. per sec and 500 in. per sec rewind are not uncommon. The unrecorded areas required for starting and stopping are being minimized; for example, one system (DATAmatic 1000) records on alternate areas in each direction and reads the tape in both directions. Improved tape drives make it possible to operate the UNIVAC II tapes with a 1-in. gap at 100 in. per sec, while the UNIVAC I tape needed a start-stop space of 2.4 in.

The ability to search independently, while the data-processing system executes its normal program, is another factor in the increased effectiveness of magnetic-tape units. The tape units provided with such processors as the Datatron, Elecom 125, and UNIVAC File Computer, among others, have this ability. The Tape Record Coordinator provides a "partial" search method in the IBM 705 system. Only the search "key word" of the tape record is read into the 705 central unit for comparison, with the remainder of the record held on the Tape Record Coordinator. This minimizes the transfer time between the Tape Record Coordinator and the 705.

Checking features incorporated in magnetic-tape-handling systems should act positively to detect lost or misinterpreted tape information. A simple example is the vertical parity bit check

on each character (odd-even check). Horizontal parity bits or record-length counts are also used. Dual recording as used in the BIZMAC, is another method of detecting errors and losses.

Peripheral equipment

A fine line of distinction can be drawn between directly connected input-output devices, and the off-line use of these devices for data-conversion operations. Where the data processing is sequential, with batching of transactions, it is usually preferable to convert input and output data to magnetic tape off line. With on-line processing, involving random rather than sequential transactions, punched-card or paper-tape units are usually directly connected on line. With the large volume of data that must be handled in business operations, it is costly to enter the original data directly on magnetic tape. Since it is possible to record most data in some machine-sensible form (such as a punched card or a paper tape) as a by-product of a normal typewriting, printing, or copying operation (such as invoice preparation on a Flexowriter, or mark-sense cards used in meter reading for public utility billing), the machine-sensible by-product can be used in automatically converting the data to magnetic-tape form.

At present, most peripheral equipment is either of the punched-card or paper-tape variety. Developments in the field of character sensing are promising, but at present are restricted to experimental applications. The Control Instrument Corp., a subsidiary of the Burroughs Corp., has a traveler's-check reader in operation at the First National City Bank in New York. A similar development by Intelligent Machines Research Corp. is being used by The Bank of America.

How equipment availability affects applications

Today's equipment allows an extremely broad view of clerical functions. In fact, many feel that the application of business-data processors must be considered from this wholly integrated and coordinated viewpoint if the expense and effort of installing and using the equipment is to be justified. It is evident that major advantages are to be gained if overlap and duplication of functions within an organization can be eliminated.

Until the advent of large-scale data-processing equipment, organizational structures were based primarily on the division of authority and responsibility in terms of manual or limited machine operations. With these structures, efficient communication facilities between organizational units often do not exist. Routine data-processing operations are relatively slow and are duplicated in various areas, files are compounded, and overall stability rests in a series of checks and balances exercised manually to afford managerial control. While it is quite possible for unit operations in any element of the organization to run efficiently, it is also quite likely that some of these operations are duplicated in whole or in part in other areas. Inventory records are a typical example: manufacturing maintains stock control records, accounting keeps inventory value records, while purchasing and sales have their own private inventory files. This situation is inevitable unless communications and data-processing ability are improved.

With the improvements offered by high-speed electronic data-processing systems, it is no longer necessary to adhere to old concepts of organization and function based largely on human effort. If there is a logical relationship between functional activities it is now possible to integrate and coordinate them.

For example, consider two major areas of organizational activity that lend themselves to integration:

1. Planning and procurement
2. Production and distribution

In planning and procurement activities there is a definite relationship between:

- product development
- engineering specifications
- parts requirements
- machine loading
- material control
- purchasing
- stores
- accounts payable
- inventory control

In production and distribution, on the other hand, the relationships are between:

- production scheduling
- production control
- timekeeping
- payroll
- inventory control
- orders
- billing
- accounts receivable
- accounting

Current activities in some industries indicate progress in integration and coordination as a result of applying elec-

FIG. 2. Bank of tape units used with RCA BIZMAC in inventory control system at Ordnance Tank-Automotive Command, Detroit. More than 2.5 million letters and numerals can be filed on a single reel.

FIG. 3. Elecom 125 system as represented by the inventory control system of Figure 1. The File Processor is at the left and the computer is at the right.

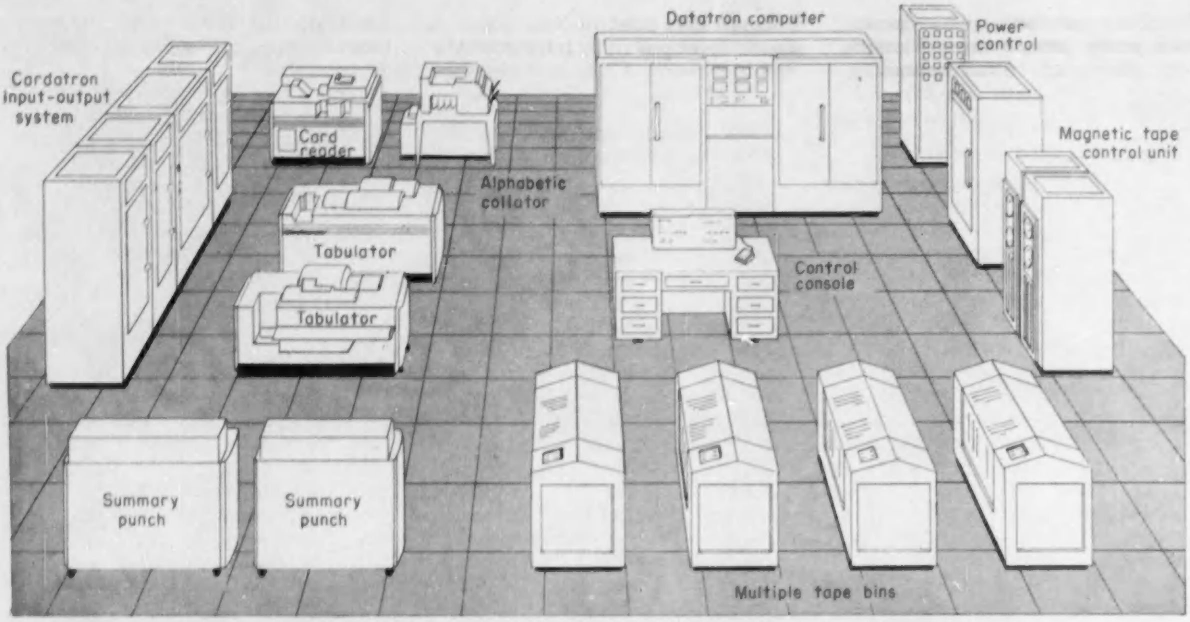


FIG. 4. Complete Datatron data-processing system. Notice random-access-memory multiple tape bins in foreground.

tronic data processors. In the public utility field, billing, accounts receivable, and meter-record and test information are to be developed as one process while maintaining a current file of operating and historical data for each customer. Also, certain public utilities plan to combine the functions of purchasing, stock control, stores accounting, and accounts payable in connection with material and supply inventories.

In general, there is a trend in the manufacturing industries toward the integration of order billing, inventory control, accounts receivable, and sales analysis with warehousing functions, including mechanization of order picking and stock replacement. Consider in this respect the two basic problems of the aircraft industry: many engineering changes with a long lead time, and a complex manufacturing process. To alleviate these problems, integration of the following areas is being considered:

master scheduling
engineering releases
parts requirements
material control
production planning
production control
timekeeping
manpower forecasting
machine loading

To show an integrated business-data-processing application in terms of actual equipment (Elecom 125 system, including File Processor), an inventory control system is flow-charted in Figure 1. Also included is a summary of operating times for the complete procedure. In this file-maintenance system, transactions are processed against master file records to update the master file and to deliver action information. The File Processor sequences input data, selects active master file items, and, in short, organizes work for the Elecom 125 computer. The summary of operating times indicates that the File Processor and the computer run about the same time. Actually, if the computer had to perform the former's tasks, it is likely that overall computer time would be increased three to four times.

The inputs to the system include issues, receipts, and contract commitments. These are analyzed to determine the current stock status for some 5,000 parts kept in various locations. Since parts usage is on an activity budget basis, anticipated usage can be predicted and this prediction compared with actual experience, so that corrective action can be taken. During the daily processing, back-ordered items are determined for expediting purposes, and the possibility is investigated of supplying demand at one point from stock at another location. Issue documents are then produced, directing the issuance of parts to the demand location from the stock location best able to satisfy the need. In addition, because of the budgeted activity parts usage program, it is possible to establish future requirements and to indicate specific contract commitment details from information contained in the master file.

This shows, incidentally, that it is possible to use a rather slow computing system, with a time-shared File Processor for sorting input data, selecting action master file records, and merging updated master file records, and still operate at a rather respectable speed.

Future trends in data processors

While the availability of electronic data processors is affecting the organization and operation of businesses, the requirements of business are influencing the design of data processors. To examine this influence, business problems can be divided into three general categories. The first includes problems that involve considerable calculation of current or historical information, with little reference to file data. These are very similar to scientific problems and are grouped under the general classification of operations research. Problems involving the optimization of facilities, maximization of profits, and minimization of costs are typical examples. The data processors best suited to handle problems of this type naturally resemble those equipped to handle scientific engineering calculations. They are characterized by high computing speed plus large high-speed internal storage capacity. The IBM 704 and UNIVAC Scientific are typical units.

The other types of business-data-processing problems are classified as file maintenance, the difference being one of degree. The number of transactions or activities in a given time period that affect the master file establishes the nature of a file-maintenance problem. If the incidence of transactions to master-file data is close to one for one, the work can be organized

to take advantage of this situation. Under these conditions, the input items are organized sequentially in the same pattern as the master file (which would probably be stored on tape). Processing consists of updating a considerable portion of the old master file, and then, since many changes occur, rewriting it on tape. Typical operations include premium billing in insurance companies and public utility billing. In these high-file-activity systems, there is usually little need for random access to stored data, everything being done at one time on a sequential basis. At present, the 702 and the 705, the UNIVAC, and the Datatron, among others, are used to handle applications of the type classified as file maintenance.

Recent developments that will affect this area of data processing include the more efficient tape units used with the DATAmatic system, and IBM's Tape Data Selector. The DATAmatic units feature a 3-in.-wide tape that can be used to read or write at a rate of over 50,000 characters per sec, while the Tape Data Selector features increased efficiency of the IBM Tape Processors by permitting off-line extraction of tape information in printed or punched-card form.

The third category includes those problems with a low ratio of activity to master file data, either because of the size of the master file or because of the low number of daily transactions. Social Security new-account applications, for example, come in at the rate of about 10,000 per day and must be processed against a master file of 120 million records. Random access devices work best in this area, since only a small percentage of the total stored items is referred to at one time. This type of work can be organized in two ways. One is to delay the processing of the transactions to provide time to locate the necessary items in a magnetic-tape master file. These can be extracted from the master file at a relatively high rate since there is no computation. Once the active file items have been extracted, they can be processed with conventional tape processors that need not operate at extreme speeds. The RCA BIZMAC, Figure 2, and Elecom 125, Figure 3, are used to handle this type problem.

On the other hand, if the transactions must be processed randomly as they occur, no appreciable time can be spent in locating master-file information. Banking operations, inventory control, and accounts-receivable operations at collection windows are typical. Various random-access storage systems are being developed to handle these problems. One of these is the DIANA bulk memory of 71 million digits, stored on magnetic drums. In this system the drums rotate at 3 rps to synchronize with input devices and an on-line printer. Thus, one rotation of the drum provides sufficient time for look-up, computation, and print-out of a transaction. In normal operation, print-out is at the rate of 150 lines per min. Sorting in the DIANA system is merely a problem of locating the next higher sequence during each drum revolution, and printing this sequence for each cycle.

Another random-access storage system is under development by the ElectroData Corp. The Datatron system will use multiple bin units, Figure 4. Every bin unit will contain 50 strips of magnetic tape, each 250 ft in length. A single reading head will scan the 50 tapes at a rate of 60 in. per sec. Maximum access is 52 sec, but normally far less time is required. One bin has a capacity of 20 million characters, with a total of 10 bins per system.

IBM's random-access disc memory, announced about a year ago, is a third system aimed at solving the random-access problem. This uses 50 magnetic discs with a total capacity of 5 million digits. Access time is approximately 0.5 sec. Current plans are to incorporate this memory in equipment especially suited to banking operations. Still another random-access large-scale memory is the Clevite Brush Tape-Drum.

Actually, most data-processing problems are rarely such that a specific data-processing system can be used to best advantage in all related tasks. Differences other than price between data processors become significant when the bulk of the work falls into one of the previously described categories. If this is the case, it becomes possible to decide that a tape-processing system will be more effective than a random-access system, or that an off-line sequential processing system will be more useful than an on-line system. However, with the diversity of most business problems, detailed studies of specific applications are usually necessary before a decision can be reached. Experience to date shows that general-purpose equipment will best fit most company's needs.

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JAMES GIBBONS

As director of the Electronics Div. of the Management Advisory Services of Price Waterhouse & Co., New York City accountants, Mr. Gibbons has conducted seminars in, and lectured to industrial, management, and university groups on, electronic data processing. He is a specialist in clerical mechanization and punched-card technology, and has been a consultant in the former field since 1947. Among the groups he has addressed are the American Management Association, the National Advisory Committee for Aeronautics, the Controllers Institute, the Systems & Procedures Association, and the Institute of Internal Auditors. In 1954 he lectured on integrated data processing at Wayne University, Detroit.

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Vapor-Pressure Analyzer Computes Liquid Concentration

L. GRIFFITH, Celanese Corp. of America*

A simple analyzer detects a liquid's vapor pressure and temperature and performs a computation on these two process variables to yield a continuous direct reading of concentration.

In the chemical industry accurate measurement of component concentration of liquids plays an important part in end-product quality. If the liquid is binary, the concentration of one of its compounds can be found by measuring the liquid's vapor pressure and temperature. As an example, Figure 1 relates pressure and temperature to per cent of water by weight in a mixture of mesityl oxide and water.

The first pressure-temperature vapor-pressure analyzer consisted of liquid-filled reference bulbs driving a mechanical system. These bulbs exert forces proportional to the compound's vapor pressure and temperature, and as Figure 1 shows, determining concentrations from zero to five per cent in this manner requires a temperature span of only 10 deg C and a pressure span of about 700 mm Hg.

Since the force generated by the bulb is the product of its applied pressure and working area, these small spans need large-size bulbs to develop the large mechanical forces. Furthermore, large bulb size means a large time constant. Therefore under dynamic conditions the instrument lagged behind the true reading, and the result was a loss of accuracy. Once the vapor pressure and temperature were obtained, a family of curves, similar to Figure 1, yielded the concentration.

Thus the original analyzer suffered from these drawbacks:

- low-resolution due to large mechanical forces required to operate the instrument
- reduced accuracy under dynamic conditions due to large time constants
- required reference forces and a calibration chart

Computes concentration

The electronic design of the new analyzer eliminates the difficulties presented by the original mechanical design. Now the process variable is simply sensed by pressure and temperature transducers and converted into electrical quantities. Since no mechanical force is required, the small-size transducers have small time constants.

The complete analyzer block diagram is shown in Figure 2. The transducers convert the process variables into electrical resistances, each serving as one arm of a resistance bridge. The inherent linearity of the transducers, together with the small bridge unbalance (because of small spans of variable), yield essentially linear signals with respect to the process variables. The bridges operate from a dc voltage source.

The instrument stores the information relating concentration to pressure and temperature in a simple computer. Examination of the equilibrium data reveals that a single expression can be developed to approximate the entire family of curves, provided that the temperature span is not too wide. The expression is:

$$ln\ (x_1 + k_1) = k_4 - k_2 T + k_3 P$$

where: x_1 = mole fraction of the light component in the liquid;
k_1, k_2, k_3, and k_4 are constants;
T = temperature
P = pressure

Thus pressure and temperature are now related by the addition and subtraction of voltages, as shown in Figure 2. Here V_2 equals the algebraic sum of the voltages representing the constant, the temperature, and the pressure. V_1 is the voltage appearing across R_a, a logarithmically wound potentiometer. The servo system compares V_1 and V_2 and drives the shaft of R_a until these voltages are equal.

The potentiometer shaft's rotation angle then represents the antilogarithm of V_2. Since V_2 equals ln $(x_1 + k_1)$, the shaft's angle equals the liquid concentration x_1. (The k_1 involves a zero correction.) Thus the rotation of the potentiometer shaft is a direct measure of liquid concentration when the temperature and pressure vary between the prescribed limits.

A pneumatic converter translates shaft position into a signal that drives the pen of a chart recorder. Thus the recorder plots, against time, the concentration computed by the analyzer directly from the measured temperature and vapor pressure.

* *Formerly with Canadian Chemical Co., Ltd.*

Fig. 1 LIQUID'S TEMPERATURE AND VAPOR PRESSURE YIELDS CONCENTRATION

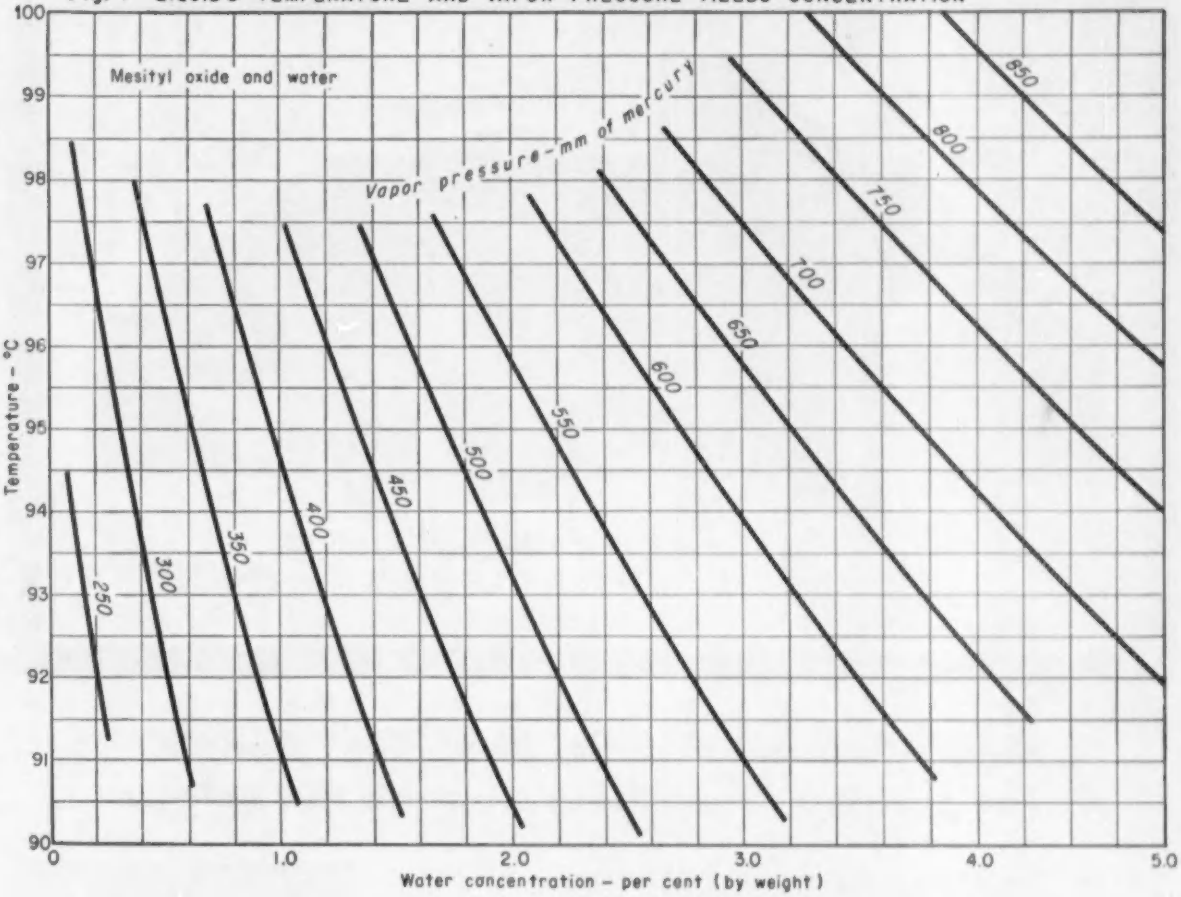
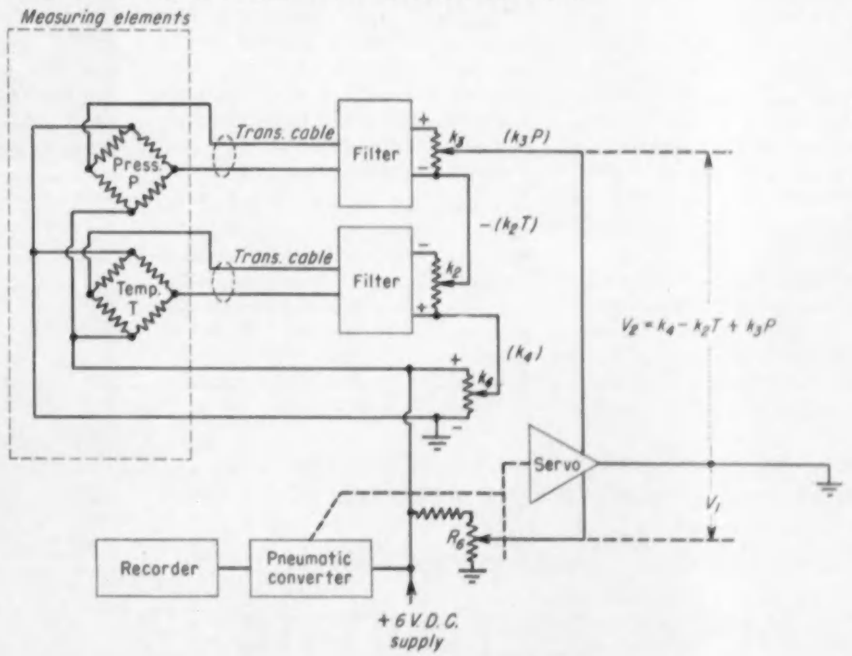
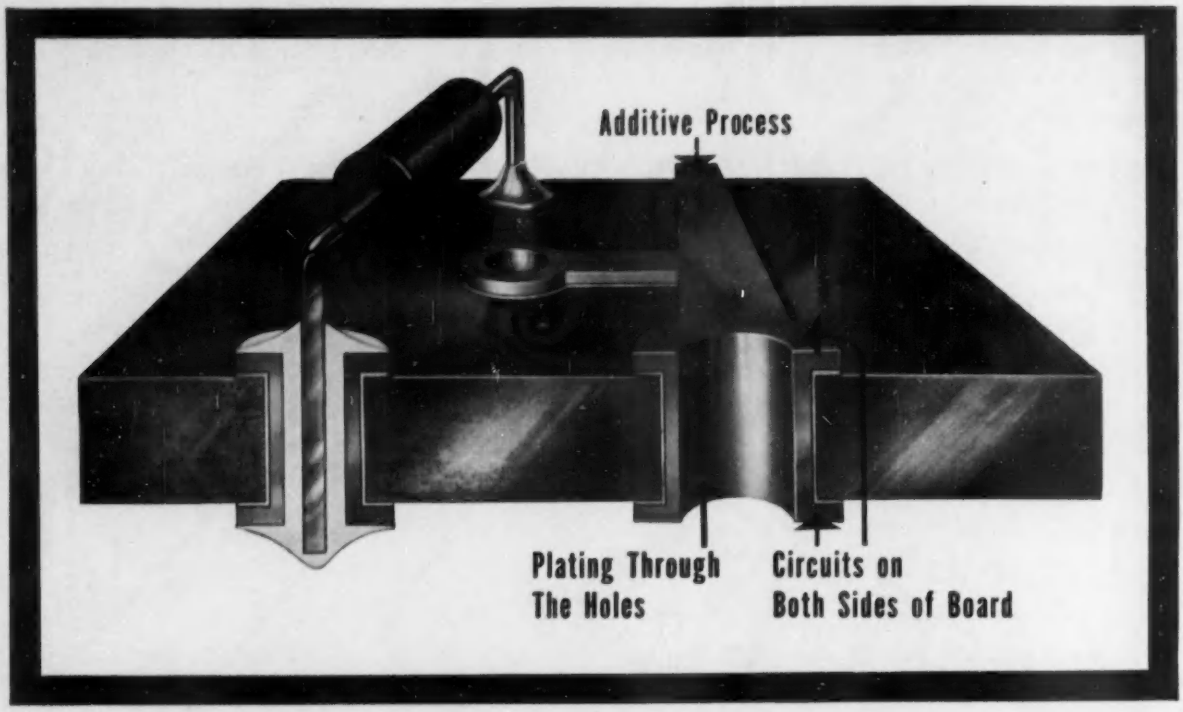


Fig. 2 ANALYZER COMPUTES CONCENTRATION





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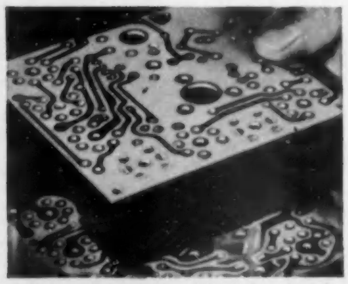

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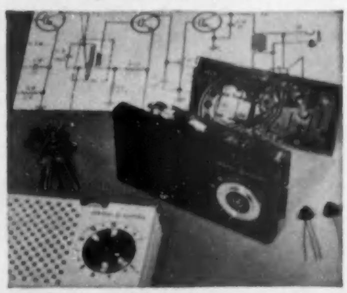

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WILLIAM M. PEASE, Feedback Controls, Inc.

By properly including the variables in the arms of a self-balancing bridge circuit, a single amplifier can serve to solve an entire equation. With precision rheostats the overall accuracy can be as high as 0.01 per cent.

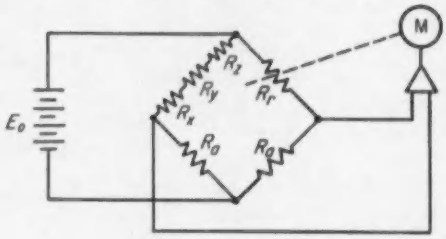
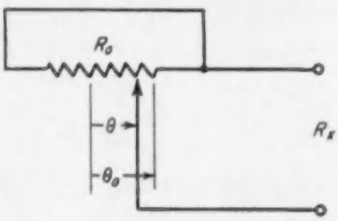


FIGURE 1

$$R_r = R_x + R_y + R_z$$



$$R_x = \frac{\left(\frac{\theta_o - \theta}{\theta_o}\frac{R_o}{2}\right)\left(\frac{R_o}{2} + \frac{\theta}{\theta_o}\frac{R_o}{2}\right)}{R_o}$$

$$R_x = \frac{R_o}{4}\left[1 - \left(\frac{\theta}{\theta_o}\right)^2\right]$$

$$\text{let } \frac{\theta}{\theta_o} = x$$

$$\text{then } R_x = \frac{R_o}{4}\left(1 - x^2\right)$$

FIGURE 2

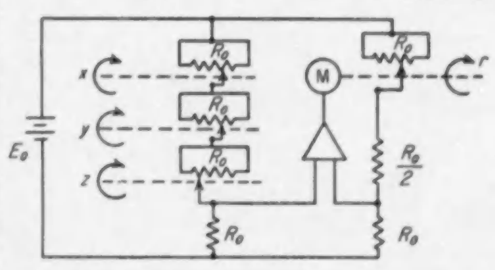


FIGURE 3

$$r = \sqrt{x^2 + y^2 + z^2}$$

A self-balancing Wheatstone bridge is often used as a computing device. With combinations of linear precision rheostats in the arms of the bridge, many of the common mathematical operations, addition, subtraction, multiplication, and division, can be done in the bridge simultaneously. Transducers whose outputs are electrical resistance changes are suitable input devices for such computing bridges.

There are available multiturn rheostats accurate to about twenty parts per million (0.002 per cent). In computing bridges, these permit overall computational accuracies in the order of 100 parts per million (0.01 per cent).

Solution of the range equation

An interesting illustration of the application of these techniques is the solution of the equation for the distance between two points in space, as stated in orthogonal coordinates:

$$r = \sqrt{x^2 + y^2 + z^2}$$

Consider the bridge of Figure 1 to be self-balancing and the arms to consist of resistances as shown. The describing equation is given in the figure. Now suppose that R_x, R_y, and R_z are identical and are formed from precision rheostats, as shown in Figure 2.

Substituting the equations for the end-connected rheostats of Figure 2 in the equation of Figure 1 gives:

$$R_r = \frac{R_o}{4}(1-x^2) + \frac{R_o}{4}(1-y^2) + \frac{R_o}{4}(1-z^2)$$

or

$$R_r = 3\frac{R_o}{4} - (x^2 + y^2 + z^2)\frac{R_o}{4}$$

Combining with the desired result, $r^2 = x^2 + y^2 + z^2$, R_r then becomes:

$$R_r = 3\frac{R_o}{4} - r^2\frac{R_o}{4}$$

or

$$R_r = \frac{R_o}{2} + \frac{R_o}{4}(1 - r^2)$$

which is a fixed resistance $R_o/2$ in series with an end-connected rheostat. Thus, a self-balancing bridge arranged as in Figure 3 will yield the desired result.

The solution of the slant range equation has been used for illustration, but there are many other useful variations of this technique.

Doelcam Selective Range

D-C PROPORTIONAL AMPLIFIER

MODEL 2HLA-4
Shown with Cabinet off for Rack Mounting

INTERCHANGEABLE RANGE PLUG-IN UNIT

Available in any range between
0 to 0.1 MILLIVOLT
and
0 to 100 MILLIVOLTS

SPECIFY AN INTERCHANGEABLE PLUG-IN UNIT THAT MEETS YOUR RANGE REQUIREMENT . . . *EXACTLY*

The Doelcam Selective Range D-C Amplifier Model 2HLA-4 is designed for use in the laboratory or production line as a component part of a control or linear measuring system. It will accept any one of a number of interchangeable Range Plug-In Units for the combination of input voltage range, input resistance and frequency response that meets your application requirements. . . . *exactly*. One Plug-In Unit is provided with each instrument. No need to pay for built-in voltage ranges which may never be used. The exclusive Doelcam Second Harmonic Magnetic Converter is used in the input stage in place of a mechanical chopper for all around improved performance. *Write for Bulletin SRA-34.*

PERFORMANCE CHARACTERISTICS

ISOLATED INPUT: *Input Terminals are isolated from amplifier circuitry and chassis ground.*
HIGH CONVERTER FREQUENCY: *2500 cps carrier, insensitive to 60 or 120 cps pickup.*
LOW DRIFT: *Less than 5 microvolts long term drift.*
LINEAR AMPLIFICATION: *Better than 1% on all ranges.*
GAIN: *Up to 10^5.*
FREQUENCY RESPONSE: *Up to 40 cps.*
RUGGEDNESS: *Withstands over-range signals up to 1500 times full scale.*
HIGH POWER OUTPUT: *Drives most commercial Pen Motors or Galvanometer Recorders.*

MODEL 2HLA-4
Shown with Cabinet on for Bench Mounting.

Doelcam

A DIVISION OF MINNEAPOLIS-HONEYWELL H HONEYWELL 1400 SOLDIERS FIELD ROAD BOSTON 35, MASSACHUSETTS

Instruments for Measurement and Control

Synchros • Gyros • Accelerometers • Amplifiers • Microsyns • Servo Motors

Low Distortion and Low Noise in Small-Amplitude Motions

Distortionless, noise-free mechanical motion at a sinusoidal double amplitude of 0.01 deg is produced by a table designed to simulate aircraft motions for instrument testing. The table has a noise threshold below one second of arc.

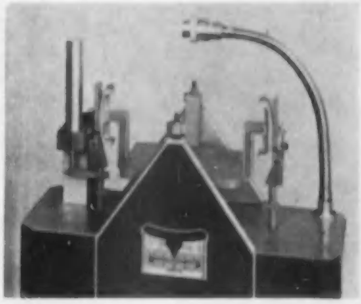


FIG. 1. Close-up of the simulation table. Amplifier and function generator are in a separate desk-top unit.

B. W. McFADDEN
Micro Gee Products, Inc.

The actual hardware of an automatic guidance or flight stabilization system is often tied in with an analog computer for a simulated flight analysis. Thus it is possible to check equipment compatibility, and actual rather than theoretical performance under closed-loop conditions.

For maximum results the gyros and accelerometers of the system under test must be included in the loop and subjected to angular displacements and accelerations in accordance with electrical signals from the computer. This requires a flight-simulation table.

The simulation table shown in Figure 1 is a high-performance servomechanism with a natural frequency in excess of 15 cps and a damping ratio that is adjustable between about 0.1 and 1.0. Its threshold is less than 5 microradians (1 sec of arc). It is designed to follow signals from an analog computer as well as from a standard low-frequency function generator. The latter is included to provide signals for dynamic tests.

Servo design considerations

The input signal is applied through the gain control, P1, and the associated summing resistor, R1. Since amplifier 1 is an operational amplifier, its transfer function is defined by the feedback impedance formed by R2, R3, C1, C2, and C3. Values are such that the first amplifier has a lead-double lag characteristic that provides error rate at low frequencies for sufficient damping of the system in its least-damped configuration, yet provides rapid cutoff at high frequencies.

Additional error rate, as well as feedback rate, is obtained when the damping control P2 is turned clockwise to increase system damping. The additional error rate is obtained through the network formed by P2, C4, and R4, while the feedback rate is obtained through the table position feedback network formed by P2, C5, R5, and R6. To keep the natural frequency of the system relatively constant while adjusting damping, the error rate part of the damping control, P2B, also adjusts open-loop gain. To minimize changes in closed-loop gain of the system this variation of open-loop gain is done in the forward part of the loop instead of in the

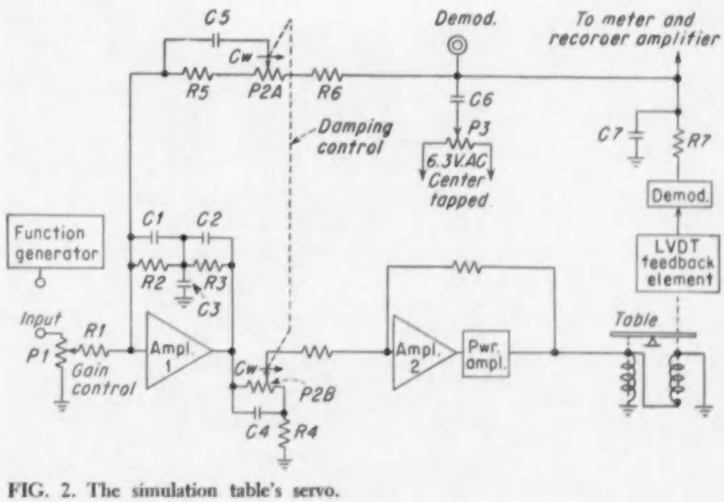


FIG. 2. The simulation table's servo.

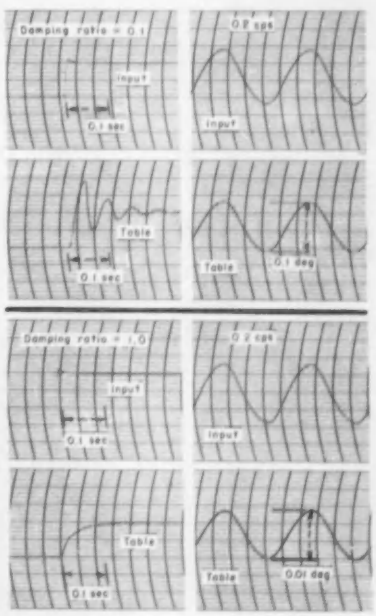


FIG. 3. Transient response of table for 0.1 deg step, and sinusoidal response for 0.1 and 0.01 deg double amplitude. Note absence of distortion and noise at small amplitudes.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feedback. Thus, the natural frequency and overall gain of the system remain essentially constant as the damping control is varied.

The power amplifier drives the coils of the table. Its output impedance is low enough to prevent loading by the coils, hence the transfer function is practically a pure gain. Load equalization can be added if a table load requiring it is ever encountered.

Table position is sensed by a linear variable differential transformer (LVDT) located on one of the rectilinear drive rods of the table. Because linear motion of the drive rods is directly proportional to rotary motion of the table, the output of the LVDT is a distortionless indication of the angular position of the table. The LVDT is an ac pickup excited by a 5-kc signal and the output is demodulated by a low-drift demodulator. The low-pass filter formed by R7 and C7 attenuates the 5-kc ripple in the demodulator output without significant phase shift at signal frequencies.

The output of the demodulator filter is supplied to the meter and recorder amplifier, to the table position feedback network, and to a test jack on the back of the chassis. Also, at this point a 60-cps hum balance signal is injected via P3 and C6 to null out any component of heater voltage induced into the amplifiers. This is necessary because the table can respond to frequencies above 60 cps.

Mechanical design

The table has been designed to minimize small amplitude distortions caused by coulomb friction, backlash, and bearing noise. It utilizes the principles of a pendulum with knife-edge bearings, as in a laboratory balance. The effective length of the pendulum is made as short as possible to minimize power required to force oscillations at other than the pendulum natural frequency. Also, pivot-point bearings are used, not knife-edges.

Power to move the table is supplied by voice coils that force the vertical rods at each side of the pendulum platform to move rectilinearly. These rods are seen in Figure 1 to have flat plates at their upper ends, tangent to curved rockers. Linear motion is converted to rotary motion without approximation because the center of curvature of the rockers lies on a line through the two pivot-bearing points. Slipping between the tangent plates and rockers is prevented by thin flexible ribbons secured to the top of each rocker and the bottom of each plate. A similar pair of pivoted rockers is mounted below the table in inverted fashion to maintain tension in the rods and ribbons at all times.

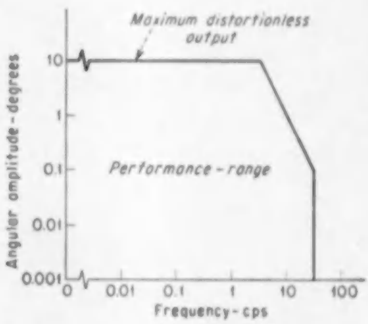
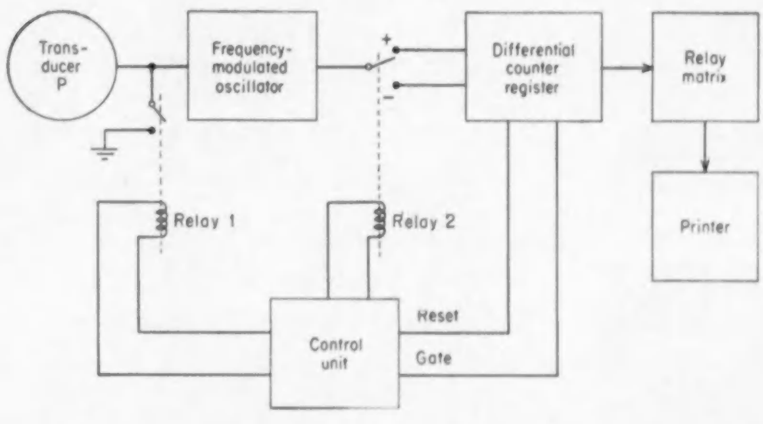


FIG. 4. Dynamic performance range. Upper frequency limit is dictated by recording problems and natural resonances in the table. At small amplitudes, distortionless motion is possible to above 100 cps.

Eliminating Digital Zero-Drift

OTTO K. KOWALLIS, Wiancko Engineering Co.



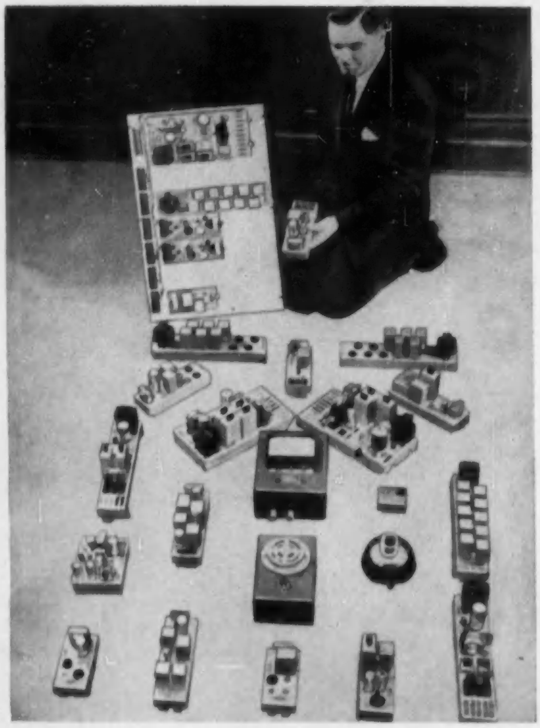
Some data-reduction systems convert a measured analog parameter into a digital value by shifting the output frequency of a frequency-modulated oscillator. The difference (frequency shift) between the oscillator's center frequency and the frequency produced by the influence of the input transducer is then a measure of the input function. However, normal drift in the oscillator (in the order of 0.5 per cent of bandwidth per 60 days) leads to errors in systems that require 0.1 per cent stability per month.

The effects of long-time oscillator drift can be reduced to an insignificant value by the approach shown in the figure. Here, when relay 2 connects the oscillator output to the + terminal, the differential-counter register runs in a positive direction. And when the relay is connected to the − terminal, the counter runs in the reverse direction. Relay 1 grounds the input terminal of the oscillator, thus preventing any transducer signal from shifting the oscillator frequency.

With relay 1 closed, relay 2 switches to the − terminal of the counter-register. Then the counter gate opens for one sec and the frequency $C + D$ enters negatively into the counter register. Here, C equals the center frequency in cycles and D equals the drift in cycles. Now relay 1 opens and relay 2 switches to the + terminal, with the consequent positive registration of the frequency $P + C + D$, for a one-sec interval. Thus, at the end of a two-sec program, the counter contains the difference in these two readings—namely P, the digital value proportional to the transducer input measurement.

Another approach would be to eliminate relay 1 but reduce the forcing function (applied to P) to zero during that portion of the cycle formerly assigned to the closing of relay 1. Hence transducer drift is now included with the oscillator drift, but both are canceled in the final answer.

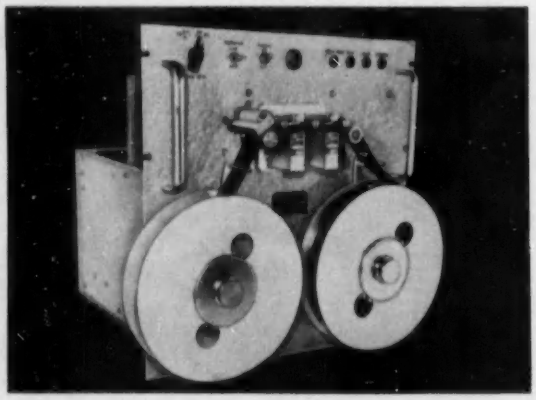
NEW PRODUCTS



21 " BUILDING BLOCKS" for control.

By proper assembly of 21 new standard components, an electronic control system that best fulfills the designer's needs can be constructed. The prefabricated modular units can be built into a versatile system that measures pertinent information and transmits it to distant control centers where the information is translated into a control function. A total of 125 channels are available for the transmission. The five basic units in the package are the controller, supervisor, transmission device, metering and recording device, and the alarm. The transmission system can be operated by bi-polar pulse sequences, time-sharing sequential links, or combinations of both. Its overall accuracy of approximately 0.5 per cent may vary with the specific transmission installation. The systems that can be built up from the blocks will control electrical, mechanical, pneumatic, or hydraulic processes. The systems will be sensitive enough to regulate fractional-hp motor actuators, powerful enough to control 1,000-hp actuators, and flexible enough to accommodate electronic computers or punched cards or tapes.—Sparks-Withington Co., Jackson, Mich.

Circle No. 1 on reply card



TAPE SPEEDS shifted electrically.

Two new tape transports for data recording emphasize flexibility. The Type 102 uses one single- or multiple-speed hysteresis synchronous motor to belt-drive the capstan. The Type 103 uses one or two single-, dual-, or triple-speed hysteresis synchronous motors to drive the capstan at any of the six different speeds, and in a wide variety of ranges, from 60 to 0.42 ips. These speeds can be switch-selected as they are produced through an electromagnetic clutch-belt-drive speed reducer.

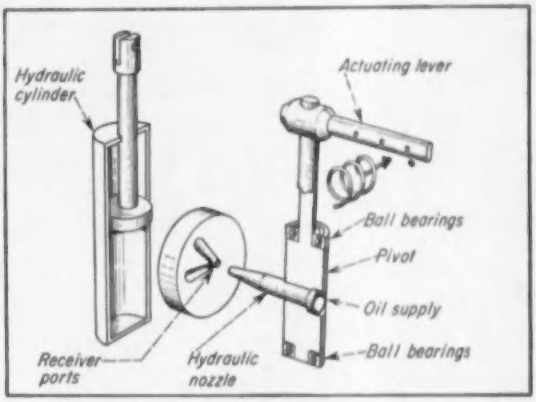
Each transport will take one or two multi-channel recording heads.—Davies Laboratories, Inc., 4705 Queensbury Rd., Riverdale, Md.

Circle No. 2 on reply card

HYDRAULIC relay has high response.

This relay is capable of a frequency response of 125 cps. It is simple, compact, rugged, leak-proof and completely sealed, and the standard unit may be operated with a supply pressure of 700 psi, giving a flow to the cylinder of 17 cu in. per sec under no-load conditions. The diagram shows all main functional parts and their relationships. The principle of operation is simple: the position of the actuating lever determines the flow of oil to the upper and lower chambers of the cylinder, where the energy of the jet stream is converted into pressure and the piston is driven in accordance with the pressure differential between the chambers.—Hauge Regulator Corp., Orangeville, Ohio.

Circle No. 3 on reply card

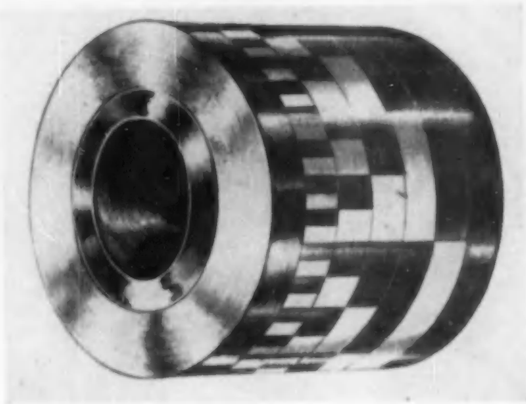


RECORDER contains dry developer.

Twenty-four individual channel galvanometer movements, with response flat to 60 cps and a natural frequency of 90 cps, provide rectilinear full-scale deflections of up to 4 in., peak-to-peak, with only 1 per cent distortion at 2 in. peak to peak, in a new high-speed recorder. It uses a dry developing process enabling the finished record to be seen after 4 in. of chart travel.

Each movement has a sensitivity switch to allow deflections of 1 in. per 20 millivolts to 100 volts. Paper speeds are ⅛, ¼, ½, 1, 2, 4, and 8 in. per sec. It's powered by standard 115 vac.—Century Electronics & Instruments, Inc., 133 N. Utica, Tulsa, Okla.

Circle No. 4 on reply card



COMMUTATORS perform at high speeds.

A rotary commutator for analog-to-digital applications is now available in stock sizes of natural binary and gray codes. The metal segments are cast in Kel-F with a location precision of ¼ deg, and then turned down to a 2-4 microinch finish. The high finish and concentricity (total runout of 0.0005) enable operation at high speeds without brush bounce, while the solid metal segments assure long life (more than 10 million cycles is claimed).

In addition to gray and natural binary codes, the maker will provide cyclic binary, binary coded decimal, or other codes.—Airflyte Electronics Co., 535 Ave. A, Bayonne, N. J.

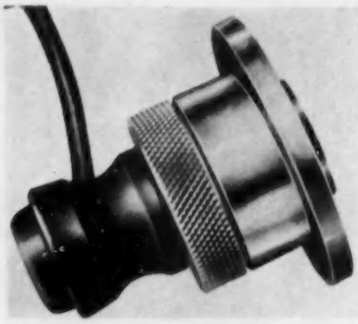
Circle No. 5 on reply card

TANK gaging system scans automatically.

This new simplified digital gaging system remotely measures liquid levels in tank farms of any size, over a single pair of wires running to the tank-farm area. It will indicate liquid heights up to 64 ft in ⅛-in. increments. The system causes the read tank to identify itself, and can automatically scan the entire farm. Coding on the two-wire transmission system facilitates printout with low-cost electric typewriters and cards or punched tapes. The system can incorporate cyclic timers to scan at preset intervals and record. In addition, it will transmit to several remote receivers.—Bendix-Pacific, North Hollywood, Calif.

Circle No. 6 on reply card

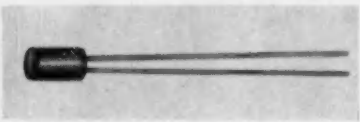
SOME DETECTORS



PRESSURE TRANSDUCER

A differential transformer is the heart of a pressure transducer excited by 2 to 20 kc. **Output at full 10-volt input is 1 millivolt per psi.** A flush diaphragm type, it can be mounted on aircraft surfaces. Pressure ranges are from 15 to 500 psi. Dimensions are about 1 in. all ways.—Schaevitz Engineering, P. O. Box 505, Camden 1, N. J.

Circle No. 7 on reply card



SULPHIDE CELL

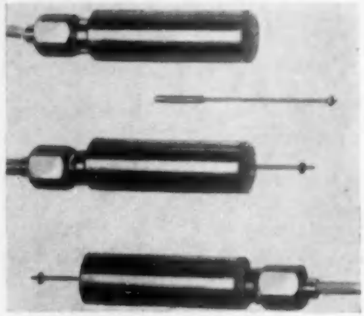
Normal daylight will provide enough energy for a new cadmium sulphide photocell to operate a sensitive relay without amplification. "Powermaster Photocells" are divided into 11 sensitivity categories. Low impedance cells are for direct relay operation, while high impedance cells are for amplifier inputs. Outputs range from 20 to 1,500 microamps (into 5 megs to 67,000 ohms) at the very low illumination of 1 ft-candle. With proper amplification, **the little cells will detect 0.001 ft-candle.** The maker says they are sensitive over the entire spectrum, with a peak to blue-green. —Hupp Electronics Co., 743 Circle Ave., Forest Park, Ill.

Circle No. 8 on reply card

SHOCK COUNTER

A compact product **counts shocks and their magnitude to four figures per g range.** Four ranges, which can be as narrow as 0.5 g, are factory set. The instrument is offered to anyone interested in recording the nature of rough treatment given aircraft, boxes, etc.—Maxson Instruments, 47-37 Austell Place, Long Island City 1, N. Y.

Circle No. 9 on reply card



LINEAL TRANSDUCER

A new variable permeance lineal transducer can be furnished for travels from 0.2 to 164 in. Intended for use in submerged applications, the new transducer presents stainless steel surfaces to the emersing fluid, and will tolerate temperatures up to 1,300 deg F.—Crescent Engineering & Research Co., 11632 McBeam St., El Monte, Calif.

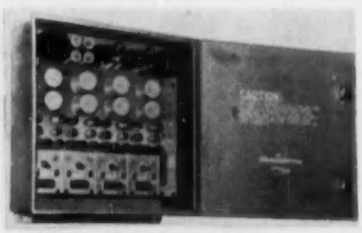
Circle No. 10 on reply card

ACCELEROMETER

A variable reluctance-type accelerometer with ranges from **5 to 300 g is housed in a ¾-in.** tube. Full-scale output is 40 millivolt per volt input. —North American Instruments, Inc., 2420 N. Lake Ave., Altadena, Calif.

Circle No. 11 on reply card

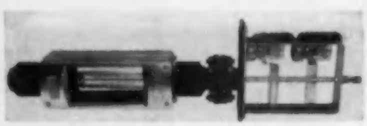
RECORDERS, INDICATORS, ANALYZERS



VIBRATION MONITOR

By detecting over-normal vibration of bearings, **a new multi-channel vibration monitor warns of impending trouble within large rotating machinery** and causes automatic shutdown. The monitor operates only after a delay period and a 4-to-1 increase in vibration level.—The Beta Corp., Forest Ave. at Ridge Rd., Richmond 26, Va.

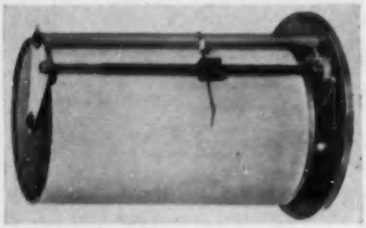
Circle No. 12 on reply card



FLOW ALARM

Said to be the first flow alarm to combine low cost with vibration-proof operation, the Fischer & Porter Ratolarm flow alarm uses two snap-action electrical contracts, hermetically sealed in a glass tube, to set off the alarm when actuated by a magnetic-float extension rod. Signals may be furnished for both high or low flow limits. The maker says that the new instrument will replace a mercury-switch and induction-coil design previously offered. Although used mainly for flow applications, the device can signal the movement of any movable device from limits.—Fischer & Porter Co., 553 Jacksonville Rd., Hatboro, Pa.

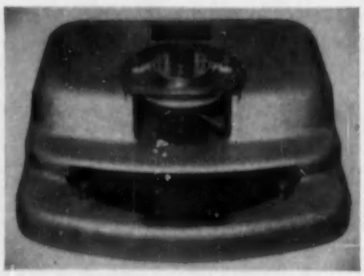
Circle No. 13 on reply card



ON-OFF RECORDER

Similar to the familiar laboratory kymograph, the operations recorder seen here uses pressure-sensitive paper to record a lot of information on a 6-by-13-in. piece of paper. Rotation of the drum moves the stylus so that 36 lines appear on the chart for a total of 400 in. By selecting a chart speed equal to a process cycle (e.g., one revolution per day) **on-off variations from day to day are immediately compared** as they appear one above the other. Drum rotation speeds range from one revolution every 4 min to one every 10 years. Prices range from about $45.—Gorrell & Gorrell, Haworth, N. J.

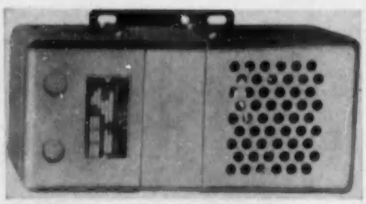
Circle No. 14 on reply card



ANGLE INDICATOR

Angles as small as $\frac{1}{60}$ deg are readable with the machine shown here. The component under test is set up in full view, held in collets which accept $\frac{1}{8}$ or $\frac{1}{4}$ in. shafts.—Waters Mfg., Inc., Sudbury, Mass.

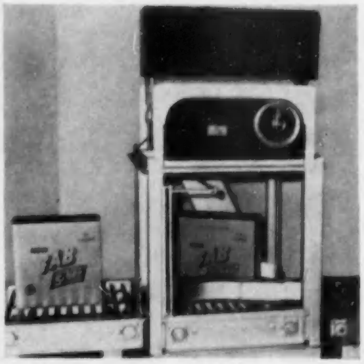
Circle No. 15 on reply card



VOLTAGE REGULATOR

A constant-voltage transformer, which **regulates within 1 per cent despite 15 per cent line** variations, has been modified to reduce its external field by 90 per cent. This permits it to be located near electronic apparatus.—Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill.

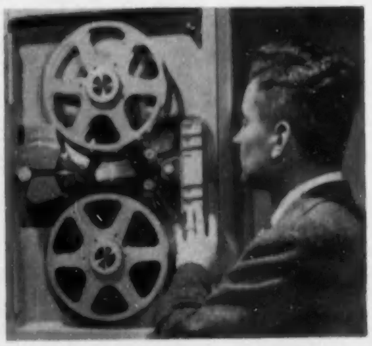
Circle No. 16 on reply card



WEIGHT CHECKER

The unglamorous-looking product shown here packs a lot of performance. It handles cartons, bags, and drums weighing from 10 to 200 lb, rejecting those that are outside of tolerance limits and indicating the deviation of those within. Tolerances are adjustable, and electrical impulse signals from the weigher **can automatically correct the filler for out-of-tolerance trends.** It can be interlocked with conveyor systems, and is available with a printout showing the weight of each item going through.—Thayer Automatic Checkweight Scale, Rockland, Mass.

Circle No. 17 on reply card



MODULAR TAPE RECORDER

Available in models having from one to 14 tracks, the FR100 series records and reproduces scientific data in the dc-to-100,000-cps frequency range. Plug-in amplifiers are available for direct, f-m, or permanent-magnet-wire recording. The six standard tape speeds range from $1\frac{7}{8}$ to 60 in. per sec. Total harmonic distortion is approximately 1 per cent, and flutter and wow are 0.3 per cent peak to peak. The unit is capable of operating over a wide range of environmental conditions.—Ampex Corp., 934 Charter St., Redwood City, Calif.

Circle No. 18 on reply card

IMPROVED PLOTTERS

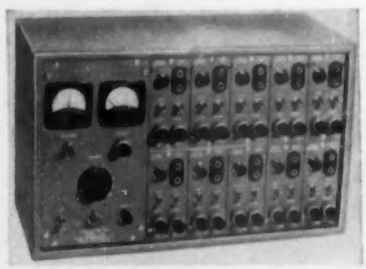
A new series of the familiar Librascope plotters features solid one-piece main casting, faster response, and greater accuracy. Input may be a 10-k pot, for which a scale of 1/10:1 to 10:1 can be used, with the zero placed anywhere.—Librascope, Inc., Glendale 1, Calif.

Circle No. 19 on reply card

DIMENSION CONTROL

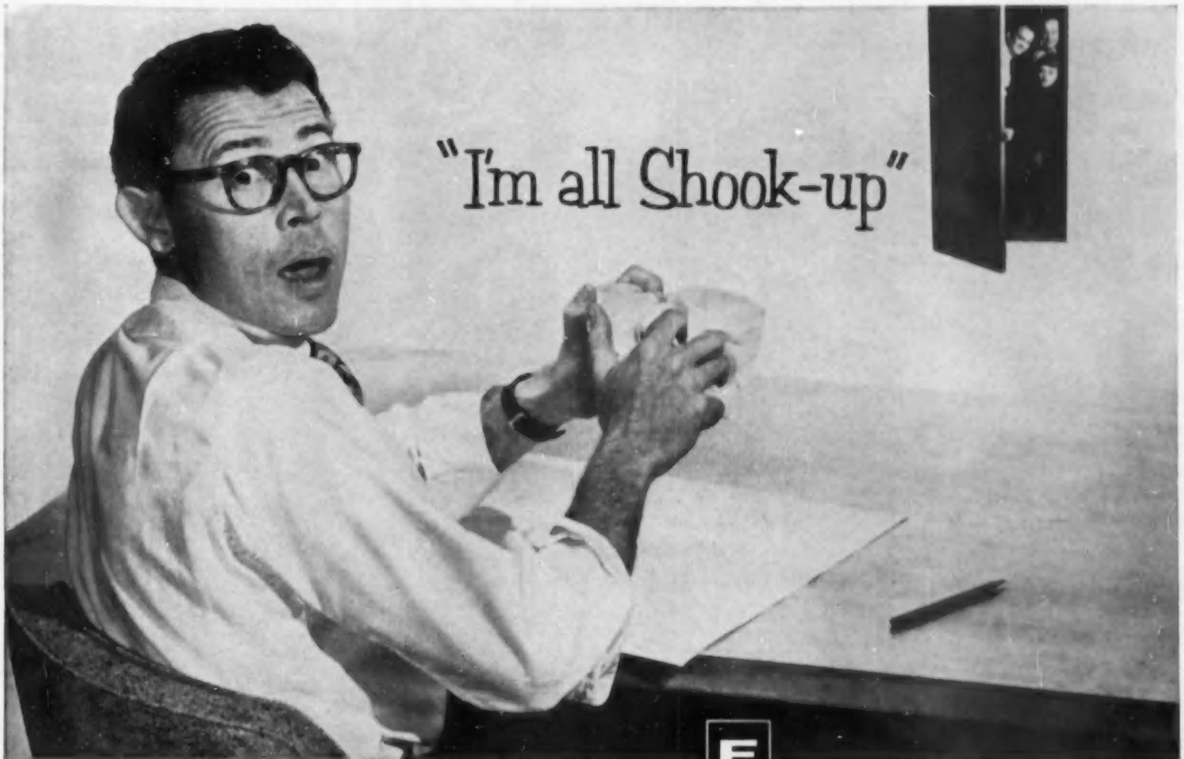
The MYKE-A-TROL **uses differential transducers with full scales from 0.1 in. to 100 microinch** to operate relays around high and low limits. Accuracy of 2 per cent is claimed. The device is offered for services ranging from metal-cutting and grinding-tool control, sequencing and inspection, to pressure control (sending a deflection).—Industrial Electronics, Inc., Detroit, Mich.

Circle No. 20 on reply card



TRANSDUCER CONTROL

One cabinet houses the means for utilizing three basic types of trans-



"I thought I had a problem but E I has my automation job done for me!"

Engineers designing precision, automatic, "fool proof" systems for measuring DC and AC voltages, DC and AC ratios, resistance, frequency—requiring both absolute and Go/No Go values—often find that combinations of standard E-I instruments give them the exact system they need—at a fraction of the cost of custom systems, to say nothing of valuable engineering time saved.

Combining E-I DC and AC Digital Voltmeters, DC and AC Digital Ratiometers, Digital Ohmmeters, Digital In-Line Frequency Counters, and Go/No Go Bridges with Input Scanners, Programmers and machine print outs provides complete systems from input to output data for automatically measuring AC and DC voltages and ratios within 0.01%, resistances to 0.01%, and frequency within ±1 digit. Reading time averages one second.

FEATURES OF E-I SYSTEMS

VERSATILITY—Combining standard, modular units provides systems that give absolute plus Go/No Go values. Changing requirements does not require equipment redesign. Operates all machine print outs.

AUTOMATIC OPERATION—Designed to eliminate hand operations from input to output data.

SIMPLICITY OF READ OUT—Combining visual, in-line read out with print out gives unmistakable results.

PRECISION PLUS SPEED—Measurements made quickly, accurately and reliably with E-I designs.

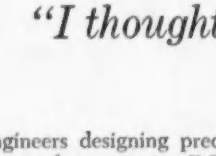
PROVEN RELIABILITY—Hundreds of rigid applications of E-I instruments and systems now in the field.

Call your E-I field representative for complete information on the variations possible with E-I instruments. He will be happy to answer questions about your specific applications.

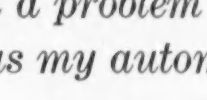
The Complete Line of Digital Instruments

ELECTRO INSTRUMENTS INC. 3794 Rosecrans Avenue San Diego, California

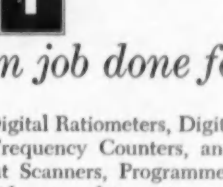
Engineering field offices in major U. S. and Canadian cities.



GO/NO GO SYSTEMS—Systems for checking AC, DC, Ω, *f* to desired limits are available for a variety of applications. The system above measures resistance differences between a number of resistors, presenting these differences as percentage.



AUTOMATIC SCANNING AND PRINT-OUT—This E-I system combines an E-I Digital Voltmeter and Input Scanner. 99 inputs are sequentially scanned automatically and values printed on a Clary printer.



TELEMETRY—E-I digital instruments are now used for precision monitoring by all major telemetry and airframe manufacturers in the United States and Canada. This system uses E-I Digital Voltmeters to operate an IBM Punch for providing data in real time.

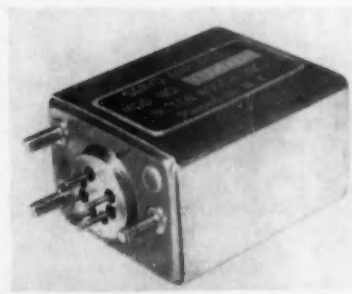
ducers: strain gage, reluctance, and potentiometer. A 3,000-cps excitation frequency and demodulator are included for reluctance units, and bridge balances for the other devices. **Ten channels are accommodated by the gear in one cabinet**, plus a stepping switch for the automatic sequential calibration of all channels.—Pace Engineering Co., 6914 Beck Ave., North Hollywood, Calif.

Circle No. 21 on reply card

METER CONTROLLER

Here's a controller that operates according to the location of a meter pointer without loading the movement, and will break up to 15 amp currents. Contacts actuated when the meter pointer interrupts a beam of light hold temperatures to within ½ per cent. A variety of temperature-sensing pickups is offered by the maker to go with the device.—Jelrus Co., 136 W. 52nd St., New York 19, N. Y.

Circle No. 22 on reply card

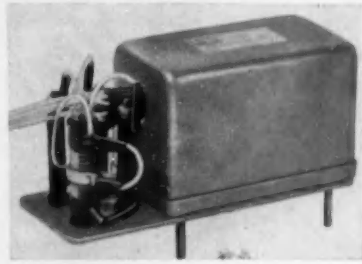


400-CPS SERVO AMPLIFIER

A new transistorized servomotor amplifier is designed for synchro control transformer input and low-impedance-winding Mark 7 servomotor output, which it will power for a 07.3 oz-in. torque. Gain is 0.36 volts per millivolt, or 70 db. Size is 1$\frac{5}{16}$ by 1¼ by 2$\frac{1}{16}$ in.—M. Ten Bosch, Inc., Pleasantville, N. Y.

Circle No. 23 on reply card

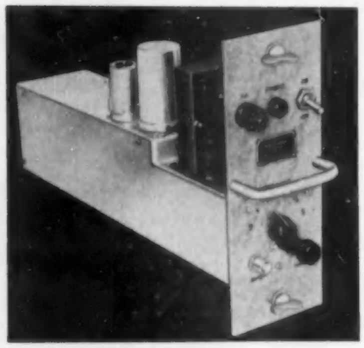
NEW PRODUCTS



ALTERNATOR REGULATORS

Four types of ac voltage regulators for 30-kw engine-driven alternators are built to military standards. Two moderately priced models, for 400 and 60 cps alternators, **regulate within 1 per cent** with response from 1 to 2 sec. A medium-priced unit, for 400 cps only, regulates within ½ per cent and in 0.12 sec, while yet another model provides ½ per cent regulation within 0.09 sec.—Arga Div. of Beckman Instruments, Inc., South Pasadena, Calif.

Circle No. 24 on reply card



TAPE ELECTRONICS

All the circuitry necessary for direct recording of a data signal on magnetic tape is built into amplifier Type 34, and everything required to read the signal back again, including equalization, is built into Type 82. **Frequency response ranges from 50 to 80,000 cps**, depending on tape speed. The little units operate directly on 115-vac power. Signal-to-noise ratio is at least 35 db.—The Davies Laboratories, Inc., 4705 Queensbury Rd., Riverdale, Md.

Circle No. 25 on reply card

TEMP SWITCH TEST SET

A new temperature switch test set operates in a range of from 200 to 1,000 deg F to indicate operating differential and calibration.—Ram Meter, Inc., 1100 Hilton Rd., Detroit 20, Mich.

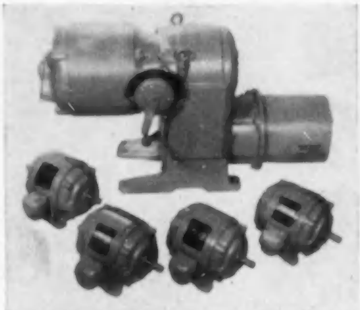
Circle No. 26 on reply card

TORQUE SOURCES

SPEED CONTROL

A new speed-control package provides continuous torque through a 25:1 speed range from a fractional horsepower motor. **Eddy current clutch coupling provides speed ratios through a range of 100:1.** Electronics control insures speed stability within 2 per cent.—Dynamatic Div. of Eaton Mfg. Co., Cleveland 10, Ohio.

Circle No. 27 on reply card



SPEED-CONTROL SYSTEM

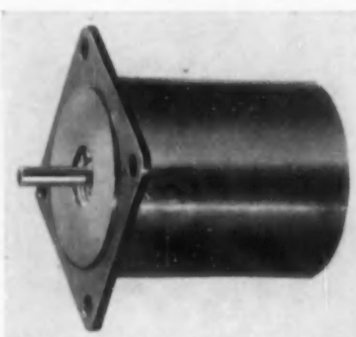
A single power unit supplies three-phase ac to **any number of motors for simultaneous speed control of them all.** A total of 50 hp can be controlled. —U. S. Electrical Motors, Inc., Box 2058, Terminal Annex, Los Angeles 54, Calif.

Circle No. 28 on reply card

GEARMOTORS

Gearmotors for ac or dc from 1 through 60 hp are said to incorporate oil seals that **allow mounting in virtually any position.**—Reliance Electric & Engineering Co., 1088 Ivanhoe Rd., Cleveland 10, Ohio.

Circle No. 29 on reply card

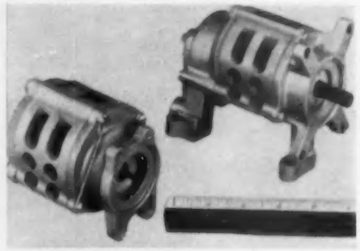


SYNCHRONOUS MOTORS

Small, light, and efficient hysteresis synchronous motors, which can turn out **up to 24,000 rpm,** are offered for

specialized instrumentation applications. The maker claims very high hp output on one-, two-, or three-phase inputs.—J. B. Rea Co., 1723 Cloverfield Blvd., Santa Monica, Calif.

Circle No. 30 on reply card



MISSILE MOTOR

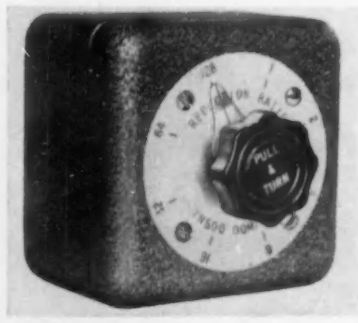
A new rugged air motor weighing but **$1\frac{1}{2}$ lb will develop $2\frac{3}{4}$ hp per 100 psi** of inlet pressure, and will accept inputs near 300 psi, producing 3,000 to 6,000 rpm. The motors can be had with governors holding outputs to within 2 per cent. Inlet gas pressures in excess of 1,000 deg F have been used to power the devices for as long as 2 min.—Bendix Pacific, 1160 Sherman Way, North Hollywood, Calif.

Circle No. 31 on reply card

$\frac{3}{4}$-IN. GEAR HEAD

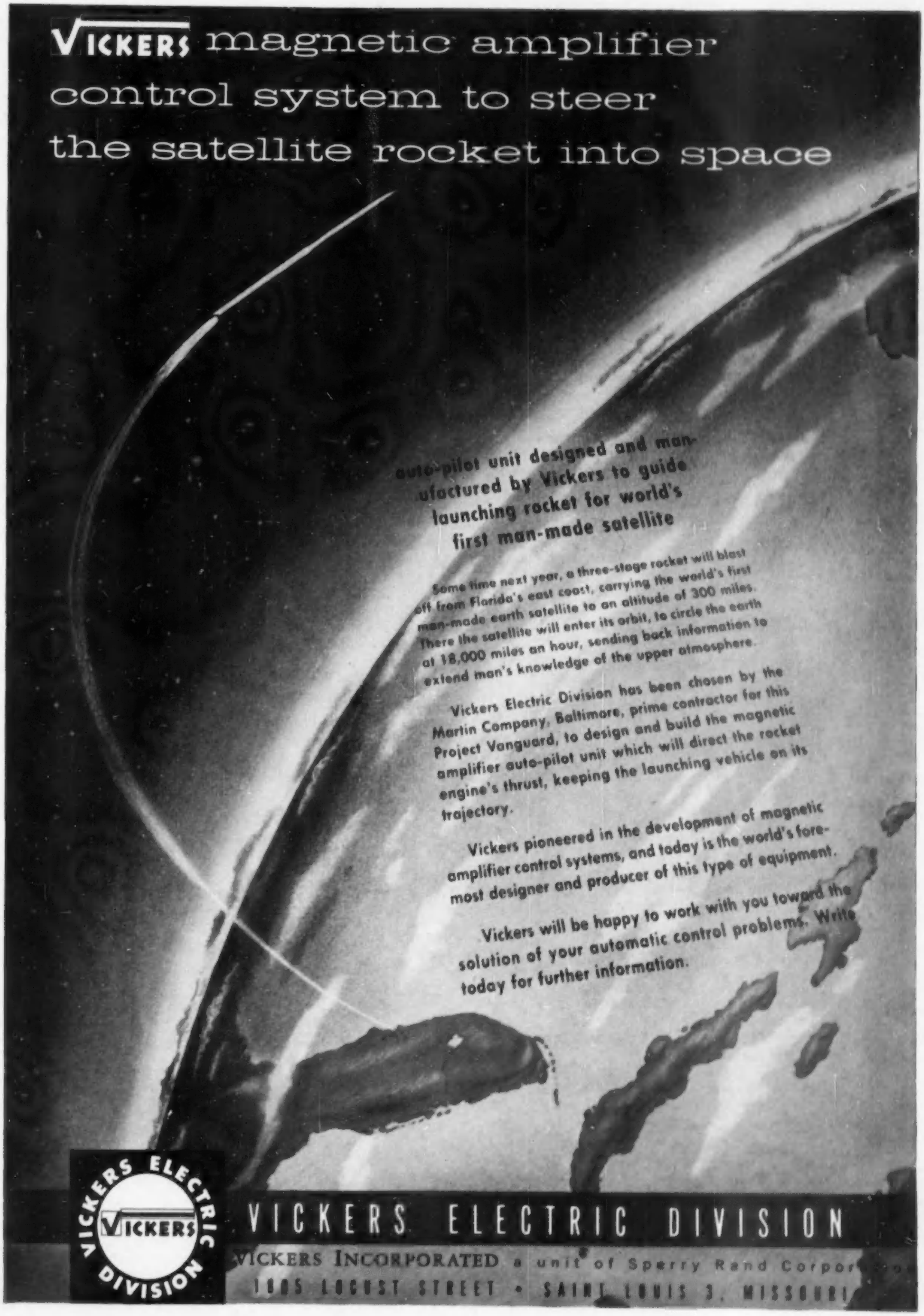
Gear head model 750-GH weighs only $1\frac{1}{8}$ oz and measures $\frac{3}{4}$ in. in diam by 1 in. long . **A starting torque of only 0.004 oz-in.** and reduction ratios of up to 650:1 suit the item for aircraft and missile control system.—Bowmar Instrument Corp., 2615 Pennsylvania St., Fort Wayne, Ind.

Circle No. 32 on reply card



DIALED RATIOS

Dial-selection of speeds plus the advantages of positive gear drives have been combined in the INSCO Step Function Speed Reduction. **Reduction ratios up to 1,500:1 for torques near 30 oz-in.** and input speeds up to 500 rpm are accomplished through a


VICKERS magnetic amplifier control system to steer the satellite rocket into space
auto-pilot unit designed and manufactured by Vickers to guide launching rocket for world's first man-made satellite
Some time next year, a three-stage rocket will blast off from Florida's east coast, carrying the world's first man-made earth satellite to an altitude of 300 miles. There the satellite will enter its orbit, to circle the earth at 18,000 miles an hour, sending back information to extend man's knowledge of the upper atmosphere.
Vickers Electric Division has been chosen by the Martin Company, Baltimore, prime contractor for this Project Vanguard, to design and build the magnetic amplifier auto-pilot unit which will direct the rocket engine's thrust, keeping the launching vehicle on its trajectory.
Vickers pioneered in the development of magnetic amplifier control systems, and today is the world's foremost designer and producer of this type of equipment.
Vickers will be happy to work with you toward the solution of your automatic control problems. Write today for further information.
VICKERS ELECTRIC DIVISION
VICKERS
VICKERS ELECTRIC DIVISION
VICKERS INCORPORATED a unit of Sperry Rand Corpor
1805 LOCUST STREET • SAINT LOUIS 3, MISSOURI

4-by-4-by-3-in. assembly.—INSCO Co. Div. of Barry Controls Inc., Groton, Mass.

Circle No. 33 on reply card

CONTROL VALVES

SOLENOID SHUT-OFF VALVE

Available in normally-open and normally-closed versions, a new dc solenoid-operated shut-off valve uses Teflon or stainless-steel sealing members. Its other features:

- pressure ranges to 3,000 psi
- temperature range from minus 65 to plus 275 deg F
- current drain from 1.5 amps at 30 vdc

Model 21A as it is called, is offered for aircraft or industrial pneumatic systems.—National Aircraft Corp., 3411 Tulare Ave., Burbank, Calif.

Circle No. 34 on reply card

PNEUMATIC CONTROL VALVE

For use as an interlocking, transfer, or sequence valve is a new ¼-in. pilot-air valve, which features a design enabling more than 3,000 different two-, three-, and four-way valves to be assembled from a few basic parts. They may be manually, electrically, or pneumatically operated. Or, two different types of operators may be assembled on the same valve. It will take temperatures to 200 deg F and pressures to 250 psi.—Industrial Products Div. of Westinghouse Air Brake Co., 1943 Herman Ave., Wilmerding, Pa.

Circle No. 35 on reply card

IMPULSE VALVE

Basic improvements are claimed for a solenoid-operated valve that requires only a triggering pulse for operation. Internal ports are ¼ in., and a wide variety of actuating schemes is available, from solenoids to buttons.—Humphrey Products, General Gas Light Co., Kalamazoo, Mich.

Circle No. 36 on reply card

... Use SIZE 8 Synchros
with No Sacrifice in Accuracy or Reliability

ILLUSTRATIONS ACTUAL SIZE

Why use 1943 Synchros in 1956 designs?

In equipment which must be flown, you want the least possible bulk and weight.

Clifton Precision's new Size 8 series of Synchros is in production and providing the highest accuracy and reliability in the industry. Samples from stock. Write or phone MAdison 6-2101 (Suburban Philadelphia)

STANDARD UNITS		ROTOR						STATOR						IMPEDANCE								
SYNCHRO FUNCTION	CPPC TYPE	Input V400cy	Input Amps	Input Watts	Ohms (DC)	Output Rotor	Sensitivity (MV/deg.)	Output Volts	Sensitivity (MV/deg.)	Input Volts	Input Amps	Input Watts	Ohms (DC)	Zro	Zso	Zrss	Phase Shift R-S	Phase Shift S-R	Nulls (MV)	Possible Error	Possible Error Spd.	Length in inches
Torque Transmitter	CGC-8-A-7	26.0	100	.5	37	—	—	11.8	200	—	—	—	12	54+j260	12+j45	76.4+j19.6	8°	—	30	7′	14′	1.240
Control Transformer	CTC-8-A-1	26.0	.050	.25	143	24	410	11.8	200	11.8	.090	.23	25	220+j740	28+j110	246+j60		8.5°	30	7′	14′	1.240
Control Transformer	CTC-8-A-4	—	—	—	381	24	410	—	—	11.8	.037	.09	60	508+j1680	67+j270	640+j190	—	9.2°	30	7′	14′	1.240
Control Differential	CDC-8-A-1	—	—	—	36	11.8	200	—	—	11.8	.085	.21	25	38+j122	27+j120	48.6+j13.8	—	9°	30	7′	14′	1.240
Electrical Resolver	CSC-8-A-1	26.0	.039	.43	230	23.2	400	10.6	180	11.8	.084	.27	27	280+j600	38+j136	70+j136	20°	11°	30	7′	14′	1.240
Torque Receiver	CRC-8-A-1	26.0	.100	.50	37	—	—	11.8	200	—	—	—	12	54+j260	12+j45	85.1+j20.4	8°	—	30	30′	30′	1.240
Vector Resolver	CVC-8-A-1	1-26	.057	.34	78	—	—			11.8	.294		27	103+j444	28.8+j27.9		10.2°	—	1MV/V			1.240

TYPICAL SYSTEM MEASUREMENTS

SYSTEM	Input V400cy	Input Amps	Input Watts	Output Volts	Sensitivity (MV/deg.)	CPPC TYPES	Input Z	Output Z	Phase Shift	Nulls (MV)	REMARKS
Transmitter→C.T.	26	.110	.74	23.6	408	CGC-8-A-7→CTC-8-A-4	58+j226	626+j233	19°+	50	Hi Z Load on CT
Transmitter→C.T.	26	.111	.75	23.3	407	CGC-8-A-7→CTC-8-A-4	58+j226		19°	50	50K Load on CT
Transmitter→C.T.	26	.111	.83	20.8	363	CGC-8-A-7→CTC-8-A-4	64+j221		17°	50	5K Load on CT
Transmitter→4 Parallel CT's	26	.145		21.8	381	CGC-8-A-7→4x CTC-8-A-4			28°	40	CT Interaction ½° Max.
Transmitter→Differential→C.T.	26	.134	1.78	19.5	340	CGC-8-A-7→CDC-8-A-1→CTC-8-A-4		748+j364	40°	40	CT Output to Hi Z
Series Vector→Electrical Resolver	1→26	.103	.67	4.9	85	CVC-8-A-1→CSC-8-A-1	55+j230	32+j68	32°	40	$E_o = .19\ E_i \sin\theta_1 \sin\theta_2$
Series Vector Resolvers	1→26	.110	.55	5.2	91	CVC-8-A-1→CVC-8-A-1			20.2°	40	$E_o = .2\ E_i \sin\theta_1 \sin\theta_2$
Transmitter→Receiver	26	.200	1.0	—	—	CGC-8-A-7→CRC-8-A-1			—	—	Torque 2400 mg mm/deg.

LOOK TO CPPC FOR **cppc** SYNCHRO PROGRESS

CLIFTON PRECISION PRODUCTS COMPANY, INC.
CLIFTON HEIGHTS **PENNSYLVANIA**

NEW PRODUCTS

SOLENOID VALVES

A new line of two-way solenoid-operated **shut-off valves for 3,000-psi service** offers extremely low leakage in the closed positions, claims the maker. Sizes available as standard are for ¼-, ⅜-, or ½-in. hydraulic tube systems. Operating range of the continuous duty coils is 18 to 30 vdc, at temperatures up to 160 deg F.—Aircraft Products Co., 300 Church Rd., Bridgeport, Pa.

Circle No. 37 on reply card

SOLENOID VALVE

A new direct-solenoid-controlled two-way valve is said to have **only two moving parts,** and both can be fully inspected by loosening one hex nut. It's available in ¼- and 2-in. pipe sizes. Coils are designed for continuous operations.—Airmatic Valve, Inc., 7317 Associate Ave., Cleveland 9, Ohio.

Circle No. 38 on reply card

GAGE SAVER

A compact little aircraft-sized valve for protecting instruments in hydraulic or pneumatic lines **shuts off flow at pressures from 50 to 5,000 psi,** tolerating a maximum of 10,000 psi.—The Fisher Controls Co., 1222 Seventh St., Santa Monica, Calif.

Circle No. 39 on reply card

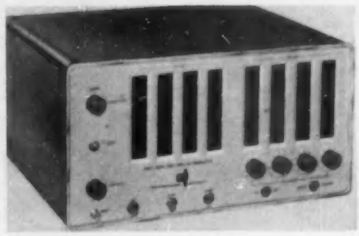
NUMERICAL IN NATURE

DIGITAL READOUT

Digital readout of Minneapolis-Honeywell Series 156 Circular Scale In-

dicators results when this decimal digit output converter is installed. It fits inside the indicator case. Output of the converter can go to an IBM punch, electric typewriter, or printer.—Hanson Gorill-Brian, Inc., Glen Cove, N. Y.

Circle No. 40 on reply card



VARIABLE TIME BASE

Rates can be measured according to time bases variable from 0.001 to 10 sec in 1 millisec steps, and 0.0001 to 1 sec in 0.1 millisec steps, and 0.0001 to 10 sec in 0.1 millisec steps. — Computer-Measurements Corp., 5528 Vineland Ave., North Hollywood, Calif.

Circle No. 41 on reply card

VARIABLE SCALE COUNTER

A new variable scale counter features neon bulb count indication and operation on 0.1 microsec, 30-volt pulses. **It can be used as a preset counter or scaler** with inputs up to 500 kc. Scale factors of 2 through 10 are available by a twist of a knob.—Burroughs Corp., Detroit 32, Mich.

Circle No. 42 on reply card

INTERVALOMETERS

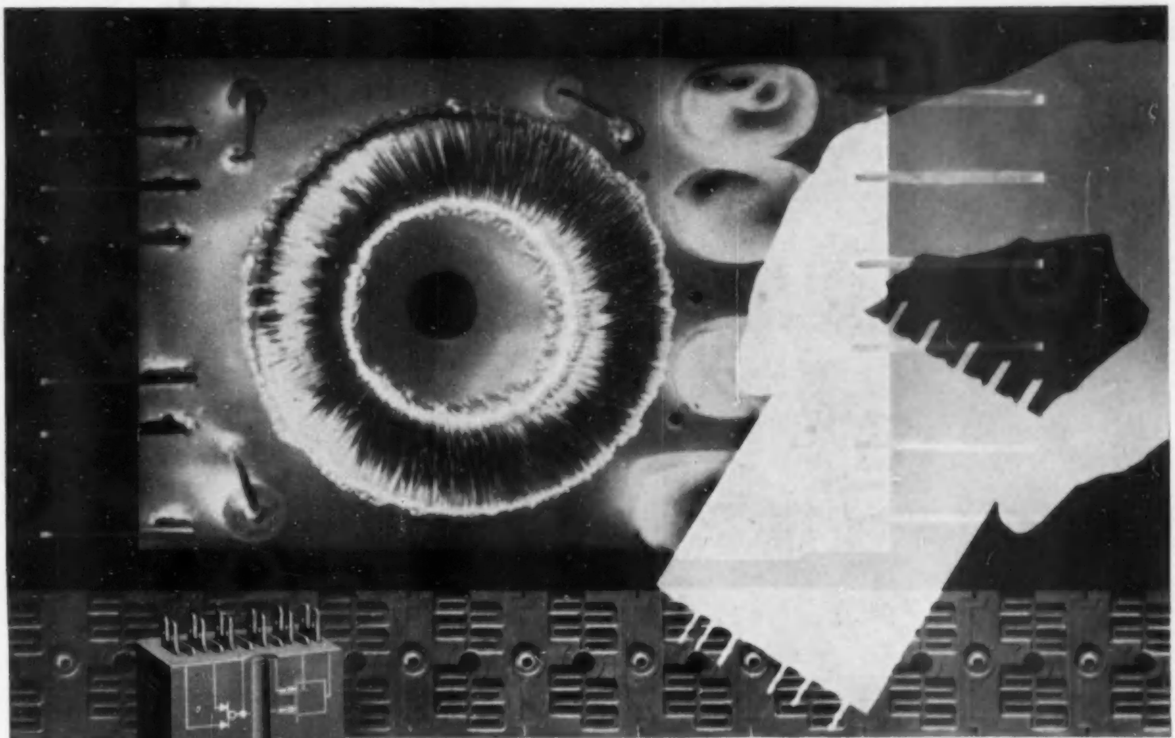
A variation of the compact digital assembly that led off the New Products section in May (page 112) is offered as a precision pulse generator or interval timer. **Intervals of 1 millisec to 1,000 sec can be selected within 1 millisec** or from 100 microsec to 100 sec in 100 microsec steps, or from 20 microsec to 10 sec in 10 microsec steps. The little dictionary-sized machines contain a crystal clock oscillator and counting circuits to obtain the claimed precision.—The Jacobs Instruments Co., Bethesda 14, Md.

Circle No. 43 on reply card

PULSE TRANSFORMER KIT

Ten Mil T-27-type pulse transformers are included in a new kit for plug-in blocking, oscillator, and impedance-matching applications.—C-B-C Electronics Co., Inc., 2601 N. Howard St., Philadelphia 33, Pa.

Circle No. 44 on reply card



THIS IS CYPAK

to eliminate maintenance on industrial control

Now you can break the downtime barrier to further expanding industrial control. Westinghouse CYPAK* provides two bold, new advantages to jump the limitations of mechanical relays.

First, unlike the mechanical relay, CYPAK has no moving parts to wear, corrode, jam or otherwise cause failure. Data processing is carried out by magnetic "make and break" of currents giving CYPAK a life at least 15 times that of conventional relay systems.

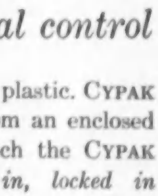
Second, CYPAK is given greater protection against the mechanical shocks and corrosive elements of industrial applications. Each component panel is sealed in a solid block of plastic. CYPAK systems are built up from an enclosed power channel into which the CYPAK elements are *plugged in, locked in* securely. Signal terminals are joined with push-on sleeve connectors.

But get all the facts on the challenging advances made in CYPAK. Call your Westinghouse sales engineer today.

J-01004

*Trade-Mark

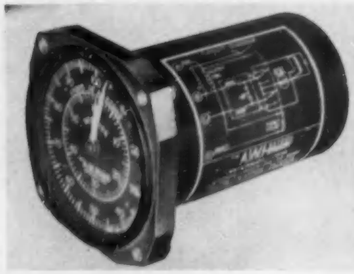
Write today for your free copy. *The Whys and Wherefores of* CYPAK, Booklet B-6584. Westinghouse Electric Corporation, 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Penna.



WATCH WESTINGHOUSE

WHERE THE FUTURE IS ALREADY IN PRODUCTION!

RELAYS & SWITCHES



DC STOP CLOCKS

The use of a governed dc motor provides a new series of stop clocks with **timing accuracy within 0.2 per cent** of reading over input variation of 20 to 30 volts. Electrical reset is featured with readings to within 10 millisec and ranges up to 1 min.—The A. W. Haydon Co., Waterbury, Conn.

Circle No. 45 on reply card

HIGH-SPEED RELAY

A new high-speed relay is said to be unaffected by shock of 30 g and vibration of 10 g at 10-55 cps. **Pull-in time is 200 microsec, drop-out 300 microsec.** Contacts are rated at 28 v 200 ma, and the whole thing is given a life expectancy of at least 1,000 hours at 400 cps operation.—The Bristol Co., Waterbury 20, Conn.

Circle No. 46 on reply card

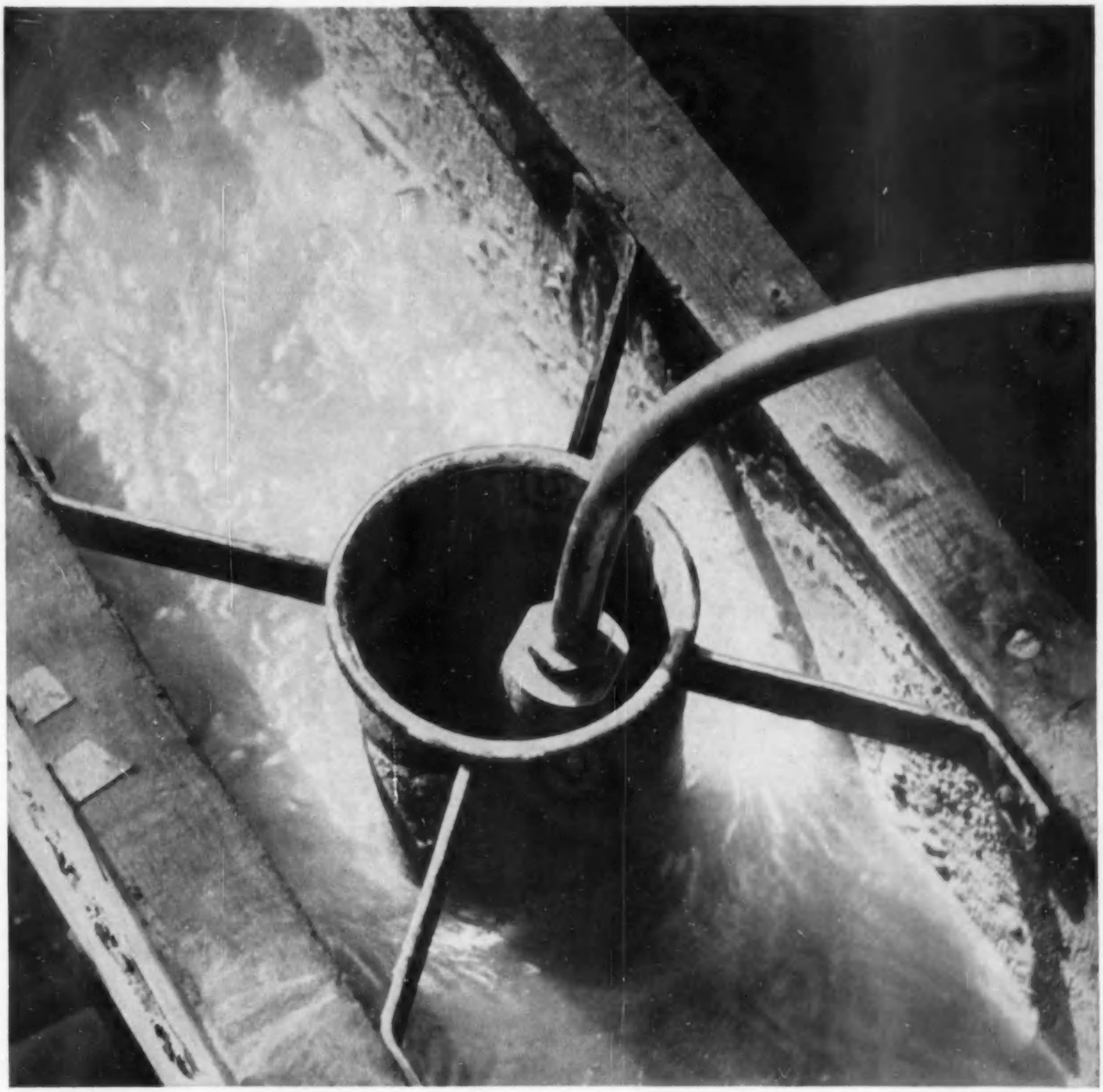
AN-DIG CONVERTER

Here's an electromechanical voltage-to-digital converter. It uses hermetically sealed relays to count at 400 steps per sec, displaying **a resolution of 12.5 microvolts.** Full scale is 999. It can be used for continuous print-out operations, with 20 readings per sec.—Non-Linear Systems, Inc., Del Mar Airport, Del Mar, Calif.

Circle No. 47 on reply card

CYCLE TIMER

Intervals from 0.2 to 200 sec "on" and 0.1 to 60 sec "off" are available to within 1 per cent accuracy with an improved repeat cycle timer using



This effluent is controlled at pH 7

. . . as it flows into a creek in northern Pennsylvania, from a large H_2SO_4 plant. It always meets State "clean streams" requirements for industrial wastes because of its L&N pH Control System which includes Speedomax recorder, L&N Control Unit, Valve Drive Mechanism, and pH electrode assemblies like this flume-mounted unit.

The first step in applying this close control is L&N's pH Controllability Analysis. This unique appraisal of the process's controllability factors (type of waste, variations in flow and concentration, etc.) tells us whether your presently-installed treating process is actually controllable within the limits you impose, and if not, what must be done to *make* it controllable. Then we translate these data into the answers you need to engineer an efficient treatment system.

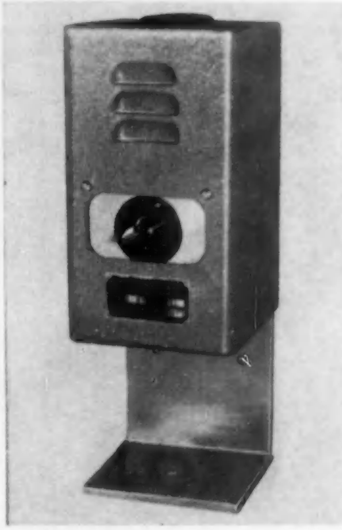
Process Data Sheet 700(2), "L&N Speedomax Control of Plant Waste Disposal Processes," explains this unique and successful approach to waste treatment. Write Leeds & Northrup Company, 4918 Stenton Ave., Phila. 44, Penna.

LEEDS & NORTHRUP
instruments · *automatic controls* · *furnaces*

NEW PRODUCTS

a radio-type tube and 2RC networks. It will handle 10 amps.,—G. C. Wilson & Co., 1915 Eighth Ave., Huntington, W. Va.

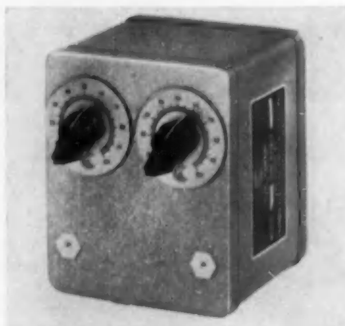
Circle No. 48 on reply card



ELECTRONIC TIMER

This compact timer includes a voltage regulator and cold cathode tube for long life and accuracy. Intervals through the ranges of 0.05 to 1 sec and 0.05 to 10 sec are dial-selected and can be actuated by momentary or continuous signals.—Post Machinery Co., Beverly, Mass.

Circle No. 49 on reply card



RECYCLING TIMER

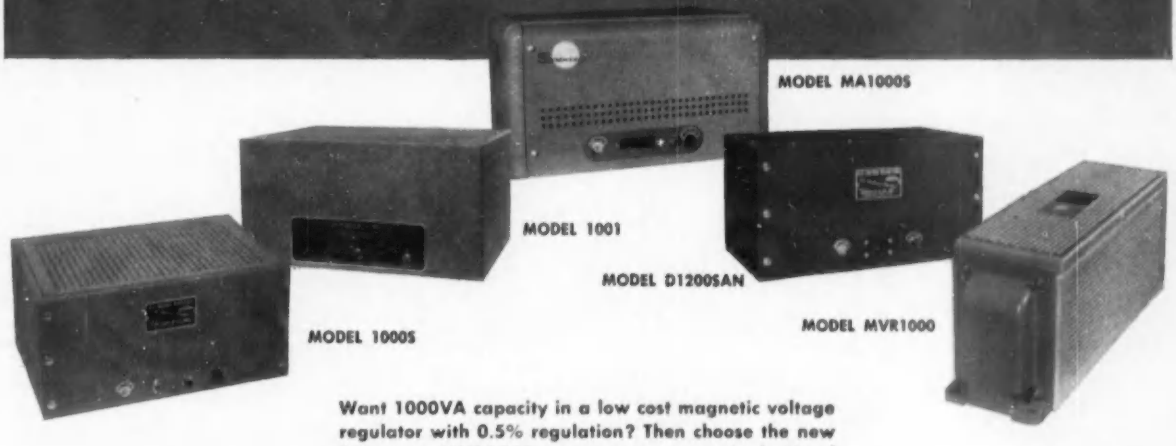
Independently adjustable "on" and "off" time ranges of 1.5 to 12 sec are standard for the Model 3CK electronic timer. It requires no warm-up time, operates on 115 vac, and handles up to 8 amps.—Farmer Electric Products Co., Inc., 2300 Washington St., Newton Lower Falls, Mass.

Circle No. 50 on reply card

SORENSEN

ENGINEERS *STANDARD* MODELS TO MEET *SPECIAL* REQUIREMENTS

to illustrate this flexibility, engineers can now choose from five 1000VA regulators!



Want 1000VA capacity in a low cost magnetic voltage regulator with 0.5% regulation? Then choose the new Sorensen MVR1000; compact, economical. Need 1000VA, but with *0.01%* regulation? Then choose Model 1001. For any requirement, any application, there's a Sorensen 1000VA unit engineered with you in mind.

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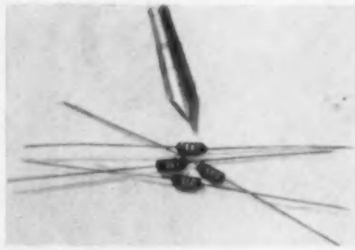

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A new terminal board kit contains 100 each of ten popular types of **solder terminals, along with anvils and punches** for assembly. All terminals are for 1/16-in.-thick boards.—Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, Mass.

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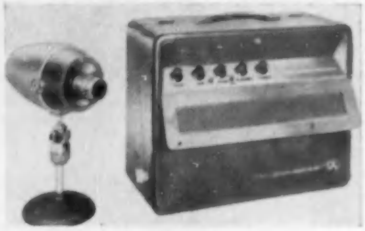
NEW PRODUCTS



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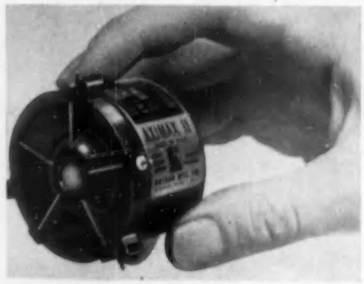

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13 watts per plate are dissipated by a Reliable Type 6080WA, now available for commercial use. It plugs directly into any 6080 or 6AS7G socket. –Chatham Electronics Div. of Gera Corp., Livingston, N. J.

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APCO's new manually operated high pressure regulator takes up to 4,500 psi and is said to contain a host of unusual features.–Accessory Products Corp., 616 W. Whittier Blvd., Whittier, Calif.

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(100) GOLD-BONDED DIODES. Clevite Transistor Products. Technical data sheets. Cover miniature diodes of glass and germanium, giving type number, forward current, inverse current, peak inverse voltage, peak operating current, etc.

(101) VARIABLE V-DRIVES. Allis-Chalmers Mfg. Co. Booklet 20P50, 40 pp. Features of this data-packed bulletin are tables that expedite selection of drives by indicating hp needs, center distances, rpm of drivers, and speed range of driven machines. Other tables cover sheaves, belt lengths, many other factors.

(102) RECORDING TAPE. Audio Devices, Inc. Bulletin, 6 pp. Notes physical characteristics, magnetic properties of magnetic recording tape for telemetering equipment, computers, etc. Two base materials: cellulose acetate and Mylar polyester film.

(103) MEASURING FREQUENCY. Sanborn Co. "The Right Angle", Vol. 3, No. 3, 8 pp. Lead article describes the Model 150-2600 frequency deviation preamplifier, which converts an unknown frequency into a proportional voltage, and then measures it. Author Arthur Miller is Sanborn's chief electrical engineer.

(104) CHART DRIVES. SAMA Tentative Standard RC 11-55-1955, 3 pp. Pertains to spring-driven, circular charts used in industrial instruments. Published by the Recorder-Controller Section, standards become firm two years from May 5, 1955, the date of tentative approval.

(105) ANALOG COMPUTERS. George A. Philbrick Researches, Inc. Bulletin, 16 pp. Gives liberal space to components (an opening table identifies each one, shows its equation, and tells what the component does); also covers operation, modular construction, applications.

(106) SWITCHES. Carling Electric, Inc. Catalog C, 12 pp. Deals with single- and double-throw switches operated by toggles, slides, knobs (rotary), and pushbuttons. Applications: aircraft, automotive, electronic, marine, motor control.

(107) LEAK-PROOF PUMPS. Chempump Corp. Bulletin 1050, 4 pp. Describes four series of "canned" centrifugal chemical pumps protected against contamination or leakage. Takes temperatures to 180 deg F, static line pressures to 150 psi, viscosities to 20 centipoises.

(108) FERROMAGNETIC PLASTICS. Polypenco, Inc. Preliminary data bulletins, 24 pp. Text and graphs present physical and magnetic properties of Ferrotran materials. Features include temperature stability to 200 deg C, moisture stability at 100 per cent room humidity, high impact strength, good machineability.

(109) METER RELAYS. Assembly Products, Inc. Catalog 4A, 40 pp. Treats six types of locking-contact meters whose relay contacts carry current to the locking coil. Reset is automatic or manual. Response measures up to ASA specs.

(110) NICKEL MAGNETOSTRICTION. The International Nickel Co. Booklet, 38 pp. A treatise by the Platinum Metals & Applied Physics Section of INC's Development & Research Div. on designing transducers using the special magnetostriction properties of nickel.

(111) LITERATURE ON NICKEL. The International Nickel Co. List A, 20 pp. Reviews an armful of INC publications on nickel alloy steels, stainless steels, nickel cast irons, nickel brasses and bronzes, and nickel plating.

(112) FLOWMETERS. Fischer & Porter Co. Catalog 10-A-25, 16 pp. Treats the 1700 Series variable-area Flowrator meter, whose tapered tube provides dynamic balance between weight of float and

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displaced fluid. Handles up to 200 gpm (water) or 400 scfm (air).

(113) SHAFT SEALS. Crane Packing Co. Bulletin S-205-2, 8 pp. Describes mechanical seals for corrosive service on rotary shafts. Heart is a Teflon wedge ring, a du Pont plastic. Take temperatures ranging from minus 200 to plus 500 deg F, and pressures to 750 psi.

(114) ELECTRONIC COMPONENTS. ACF Electronics Div. of ACF Industries, Inc. Assorted bulletins (stapled), 18 pp. Cover a vibration calibrator, tube and delay-line computer packages, a miniature transmitter, printed microwave components, and a few others.

(115) POWER-ACTUATED VALVES. The Fluid Controls Institute. Booklet, 12 pp. Details a standard classification and terminology system for these valves, the result of a project undertaken by FCI to "clear up existing semantic ambiguities and uncertainties" and to give credit to new and accepted names and terms.

(116) MEASURING WITH DIGITS. Non-Linear Systems, Inc. Catalog 356, 28 pp. Gives generous space, after a leisurely start, to eight of NLS' 21 digital voltmeters. Characteristics of all 21 are then tabulated. The rest of the bulletin describes readout systems, converters, ohmmeters, recorders.

(117) STRAIGHT-THREAD FITTINGS, L&L Mfg. Co. Catalog ST-56, 24 pp. Illustrates about 45 fittings, each incorporating one of three basic designs: captive-nut (no O-ring), metal ring seal, and a new O-ring. Charts indicate sizes, part numbers, dimensional data.

(118) AIR VALVE. Simplex Valve & Meter Co. Bulletin 200, 10 pp. Describes a "quick opening, controlled closing" air valve, which protects pipelines against destructive effects of water hammer or severe pressure surges. Closure times range from 30 sec to several minutes.

(119) ELECTRONIC PARTS. Whitso, Inc. Brochure, 14 pp. Covers stand-off and feed-through terminals and plastic and Nylon components, the latter including melamine jacks, pointer knobs, and custom-molded products.

(120) CONTROL VALVES. Valvair Corp. Bulletin SK356, 6 pp. Deals with single- and double-solenoid air, hydraulic, and vacuum valves rated at more than 25 million cycles and guaranteed against coil burnout. Air, hydraulic pressures 0-250 psi.

(121) DC AMPLIFIER. Fielden Instrument Div. of Robertshaw-Fulton Controls Co. Instrument data sheet 80-1, 4 pp. All about a temperature-, voltage-, and current-measuring instrument with good zero stability and speeds of response (for the various models) of 0.01 to 0.3 sec.

(122) SOLENOIDS. Comar Electric Co. Bulletin 200, 6 pp. Data on continuous- and intermittent-duty solid-frame units (ac and dc) and laminated units (ac) include operating voltages, cycles of operation and length of time current passes through coil, max stroke, max pull.

(123) PRECISION BEARINGS. Industrial Tectonics, Inc. Catalog AFB-1, 32 pp. Dimensions and load ratings cover single-row, double-row, deep-groove-radial, and angular-contact anti-friction bearings for special applications. Sizes range from ⅛-in. bores to 24-in. OD.

(124) SILICON RECTIFIERS. Transitron Electronic Corp. Bulletins TE 1335-36-38, 12 pp. in all. Show typical temperature characteristics and current-rating curves for military-type, miniature, and lead-mounted power rectifiers. All designed for temperatures up to 150 deg. C.

(125) MINIATURE CONNECTORS. Electronics Div. of Gorn Electric Co. Bulletin, 4 pp. Series of connectors covered: 2,000 deg F, high voltage, printed circuit, rapid disconnect, rectangular, hexagon, and pressurized.

(126) VACUUM-TUBE VOLTMETER. Hycon Electronics, Inc. Bulletin, one sheet. Tells about a direct-reading, rack-mounted instrument accurate to 1 per cent full scale on dc and resistance, 2 per cent full scale on ac. Ranges: 0-1,000 volts ac and dc, 0 k to 10 megohms resistance.

(127) PERIODICAL. A. Daigger & Co. "Apparatus Digest", 16 pp. Lead article, by T. S. Hodgkins, V-P of Reichhold Chemicals Co., contains some interesting suggestions to industry and educators for alleviating the shortage of scientists and engineers. It is the first of a series contemplated by the "Digest".

(128) FRACTIONAL-HP MOTORS. Redmond Co., Inc. Form RB-400, 12 pp. Horsepowers of motors described range from 1/50 to ¼. Classes include permanent split capacitor, shaded pole, shaded-pole mono, and series or shunt. Blowers and special products also treated.

(129) TRANSFER SWITCHES. Automatic Switch Co. Publication 596, 16 pp. Discusses "Factors to Consider in the Selection of Automatic Transfer Switches". Covers capacity, rating, transfer speed, temperature, design, double-source control, time delay, accessories.

(130) AUTOMATIC GAGING. Federal Products Corp. Catalog 56AM, 26 pp. Describes applications, characteristics, signal units, gages, and components for electric, air-electric, electronic, and air-electronic gaging, discusses "on machine" and "after machine" methods.

(131) PHASE COMPARATOR. Link Aviation, Inc. Bulletin LP 3525, 6 pp. Treats device for determining phase relationships in computers, servos, etc. Range is 60 cps (accuracy to $\frac{1}{10}$ milliradian) to 400 cps (accuracy to ¼ milliradian).

(132) CIRCUIT SELECTORS. G. H. Leland, Inc. Bulletin 456 CSR, 11 pp. Illustrates functions achieved by combin-

ing a rotary solenoid and power-operated rotary switch. Among them: stepping, counting, adding, subtracting, latching, and circuit-selecting. Wafer sections produced for 8, 10, 12, 18, 24 positions.

(133) VALVES. The Mercoid Corp. Catalog V-55, 20 pp. More than 35 valves, some falling into the categories of gas, Hydramotor, and magnetic, and some not, are described here. Compressible fluid, liquid flows charted.

(134) PORTABLE COMPUTER. Litton Industries. Booklet, 12 pp. Gives background, and design, operating, programming, application data on the Litton 20, a twenty-integrator digital differential analyzer of the portable, plug-in variety.

(135) PRINTED CIRCUIT TOLERANCES. Photocircuits Corp. Technical Bulletin P-9, 2 pp. These "standards" cover diameters, locations, hole-to-pattern tolerances, alignment, dimensions, line width and spacing, plating, circuit pattern-to-OD dimension tolerances, etc.

(136) RELIEF VALVES. Fluid Controls, Inc. Catalog 551, 16 pp. Engineering drawings, performance charts, specs describe such basic relief valves as pilot, differential-piston, guided-piston, spring-loaded, dual-relief. A separate section covers 30 other models.

(137) ASSEMBLY KITS. Servo Corp. of America. Brochure TDS 1110, 16 pp. New components are some of the features of the Servoboard electromechanical kit described here. Also new: tapped holes in the mounting board, one-piece hangar mounting clamp with captive screw.

(138) POTENTIOMETERS. General Controls Co. Catalog. Specs, drawings, photographs, etc., deal with rotary, linear, multi-turn, and sector precision potentiometers made by GCC's PP Div.

(139) RESISTORS. Hycor Div. of International Resistance Co. Bulletin PH, 4 pp. Tables covering axial-lead, printed-circuit, radial-lead, and solder-lug precision wire-wound resistors show resistances of 1 ohm to 7 megohms, 1 ohm to 2 megohms, 1 ohm to 20 megohms, and 1 ohm to 20 megohms, respectively.

(140) AUTOMATION COMPONENTS. Automatic Temperature Control Co. Catalog D-31, 20 pp. Products discussed include time controls, valves, counters, and an electronic contactor. The Atcotran system (transducer-transmitter, amplifier, and servo), other control systems also described.

(141) CATHODE-RAY TUBES. Allen B. Du Mont Laboratories, Inc. Data Sheet. Lists principal physical and electrical characteristics and applications of 74 "custom-line" CRTs for radar, oscillographs, flying-spot scanners, storage, display, and pulse and microwave use.

(142) RECTILINEAR RECORDING. Photron Instrument Co. Bulletin, 4 pp. Interchangeable recording methods (from rectangular coordinate, with hot stylus or ink, to curvilinear) is said to be the new feature of Photron's multi-channel direct-writing oscillographs, described here.

(143) COUNTERS. Production Instrument Co. Catalog M 200, 8 pp. Covers stroke and revolution counters, rated from 1-3 billion counts, special counter assemblies, and individual number wheels, reset gears, shafts, etc.

ABSTRACTS

Improving Response

From "A Dual-Mode Damper-Stabilized Servo" by J. Jursik, Clevite Research Center, and J. F. Kaiser and J. E. Ward, Servo Lab., MIT. ASME taper 56-IRD-6, presented at the Instruments & Regulators Div. Conference on Nonlinearity in Control Systems, Princeton, N. J., March 26-28, 1956.

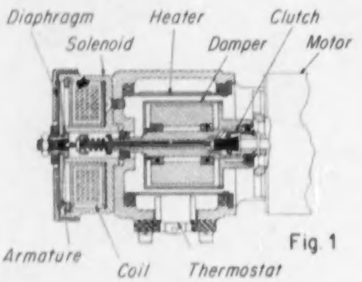


Fig. 1

The dual-mode damper-stabilized servo (Figure 1) minimizes overshoot and reduces settling time where large disturbances occur. It alters the coupling between the stabilizing damper and the motor and load, thus allowing the servomotor to accelerate rapidly and slew the system to the command point.

It is not possible to attain this improved transient response in cases where the damper is connected to the servomotor, for here the servo-amplifier provides only voltage amplification. The damper must disengage for large errors, a dual-mode operation illustrated by the block diagram in Figure 2. The figure shows that a coarse error exceeding a certain value actuates the clutch to accomplish the disengagement.

Once the error diminishes to near zero, the damper reconnects to the servomotor and behaves as an inertia brake. Synchronization follows.

Two devices were developed to actuate the clutch by predetermined coarse error voltages: one uses a relay and the other a magnetic amplifier. Although both worked well in the laboratory, environmental requirements under field conditions dictated the use of the magnetic amplifier, as shown in Figure 3. Here the coarse voltage is detected and amplified and applied to the control winding of the magnetic amplifier in the final output stage of the amplifier. The solenoid winding of the clutch operates from the load winding of the magnetic amplifier in series with an ac source and a silicon diode.

Fig 3

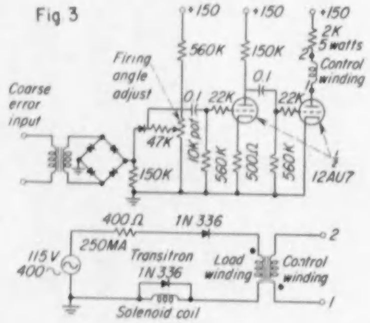


Figure 4 compares improvements in transient response obtained with the dual-mode damper and its single-mode counterpart. This response was obtained for a 53-deg error.

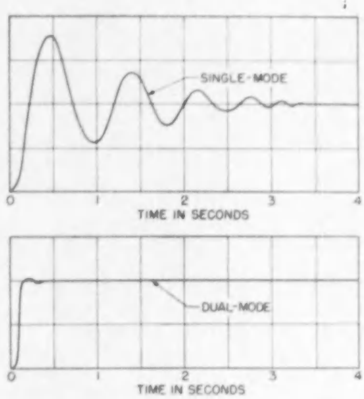


FIG. 4

Also discussed in this paper is the use of a slip-clutch to effect similar improvements in stabilizing a damper-stabilized servo. Graphs show the transient response to the servo, for single-mode, dual-mode, and slip-clutch design, at various magnitudes of error. As pointed out, the slip-clutch proves advantageous under certain conditions, but from a practical point of view, its reliability in stabilization depends on maintaining a constant value of slip-torque. This is a difficult requirement in mechanical design.

The appendix to the paper covers the derivation of the transfer function for the damper-stabilized system, based on the schematic of the damper-motor combination. The resulting transfer functions are then placed appropriately within the block diagram of the servo system.

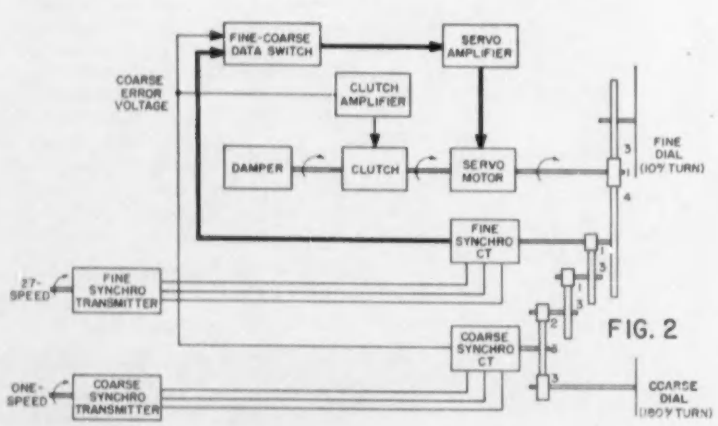
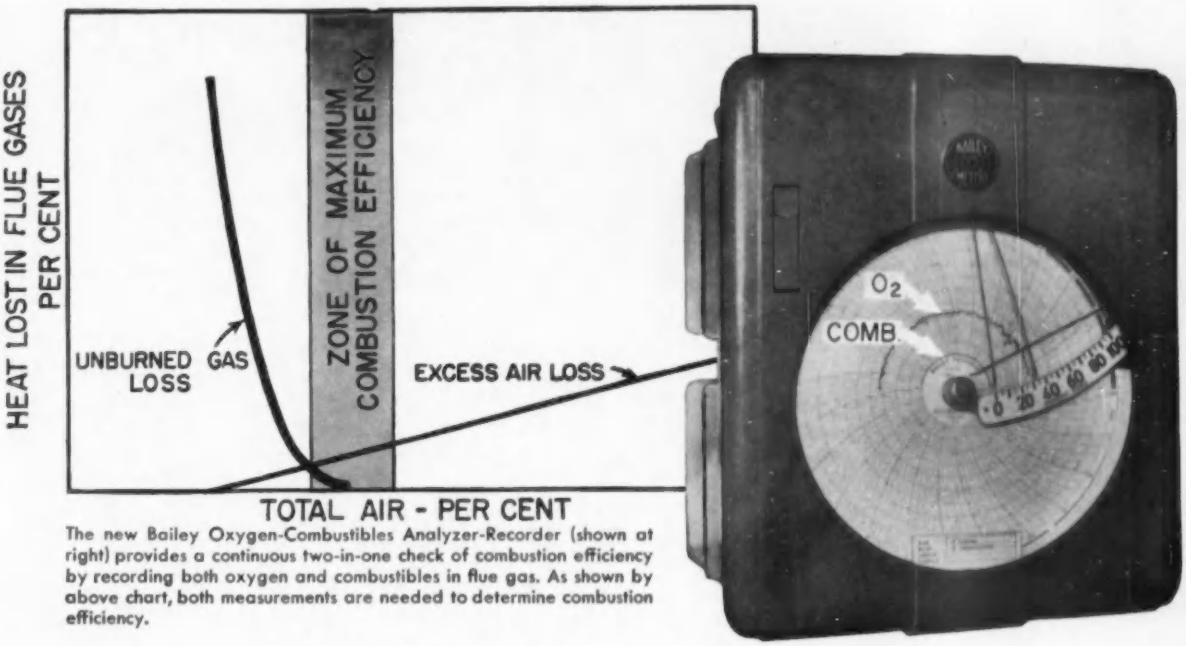


FIG. 2

Tubing Analyzed

From "On The Dynamics of Pneumatic Transmission Lines" by C. P. Rohmann, Minneapolis-Honeywell Regulator Co., Brown Instrument Div., and E. C. Grogan, Radio Corp. of America. ASME paper 56-SA-1, presented at the Semi-Annual Conference, Cleveland, June 17-21, 1956.

The authors analyze the pneumatic transmission line to determine its distributed parameters. And after doing so, they borrow from previous investigations performed by electrical engineers on analogous electrical distribution lines. Thus once the parameters of the tubing are known, the loading it



The new Bailey Oxygen-Combustibles Analyzer-Recorder (shown at right) provides a continuous two-in-one check of combustion efficiency by recording both oxygen and combustibles in flue gas. As shown by above chart, both measurements are needed to determine combustion efficiency.

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INSTRUMENTS AND CONTROLS

For Power And Process

imposes on pneumatic devices, as well as the relation between device output and the signal received at the end of the transmission line, can be determined.

However, the mathematics appear somewhat formidable. Fortunately, the authors have a sense of practicality. Not only have they performed an erudite task well, but they have made some general assumptions that go far toward simplifying matters. In particular, the results for the standard $\frac{3}{16}$-in. ID, $\frac{1}{4}$-in. OD drawn copper tubing are shown in numerous graphs.

The first step in the presentation covers the derivations of the resistive, inertance, and capacitive tubing parameters. The results of the derivation are, briefly:

$$R = 1.2\left(\frac{8\,\mu}{\pi r^4}\right)$$

$$L = \frac{\delta}{\pi r^4}$$

$$C = \frac{\pi r^2}{np}$$

where: R = resistance per unit length, $\frac{\text{lb-sec}}{\text{in.}^5} \Big/ \text{in.}$

L = inertance per unit length, $\frac{\text{lb-sec}^2}{\text{in.}^5} \Big/ \text{in.}$

C = capacitance per unit length, $\frac{\text{in.}^5}{\text{lb}} \Big/ \text{in.}$

μ = viscosity, $\frac{\text{lb-sec}}{\text{in.}^2}$

r = tube inside radius, in.

δ = mass density, $\frac{\text{lb-sec}^2}{\text{in.}^4}$

n = polytropic exponent

p = pressure deviation from mean, psi

The next section of the paper develops the transmission-line equations for the tubing. In doing this the authors use the surge impedance and propagation constants, well-known to electrical engineers. These characteristics depend on the distributed parameters. From these characteristics are developed the input-output pressure ratio vs. frequency, or transfer function, and the driving point impedance of the tubing. The authors include two charts to yield the hyperbolic functions, and two charts that show the propagation constants and the surge impedance for the standard tubing.

Because much investigation of pneumatic control systems are performed

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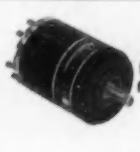

Precision RESOLVERS and PHASE SHIFTERS

SERVO MECHANICAL PARTS

on analog computers the authors also include the lumped parameter approximations for the pneumatic transmission line. Thus, within limits of accuracy depending on the extent of the approximation, the transmission line can be simulated by lumped-parameter electrical components on the computer.

The work of the authors is doubly meritorious. In addition to developing the mathematical relationships that describe the dynamics of pneumatic transmission lines, they verify their findings by tests on standard $\frac{3}{16}$-ID tubing. Although some of the tests differ from the theoretrical (and the authors explain the reasons for these differences) most of the tests do track the calculated values to a high degree of acceptability.

The graphical results should prove useful to the engineer engaged in the design of pneumatic control systems. The wide range of tests may very well contain information under conditions near to those the reader is considering. Basically, the tests fall into three categories: 1) comparison of driving point impedance (magnitude and phase shift) vs. frequency for several lengths of tubing, 2) determination of the tubing propagation constants and surge impedance from "long-line" frequency-response data, and 3) determination of the frequency-response curves for several lengths and terminal volumes.

In the third category, the authors plot:

- output/input frequency response of 116 in. of $\frac{3}{16}$-ID copper tubing terminated in 92.5 cu in.
- output/input frequency response of $\frac{3}{16}$-ID dead-ended (1.2 in.^{3} terminal volume) transmission tubing with a length of 210, 310, and 410 ft.
- output/input frequency response of $\frac{3}{16}$-ID transmission tubing with a length of 210, 310 and 410 ft, terminating in a large volume (96 in.^{3})

Some interesting conclusions extracted from the paper:

- analysis brings out the advantage of using a valve positioner or volume booster to take the load of the valve top off the transmission line and thereby speed up the transmission.
- for tubing lengths exceeding 150 ft and at frequencies above 4 cps the driving point impedance approaches the surge impedance of the tube with increasing frequency and hence tends to be independent of tubing length and size of the terminating load. A

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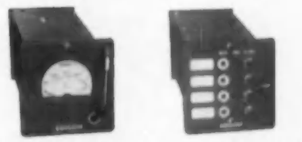

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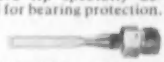

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similar situation applies for lengths over 200 ft and ½ cps.

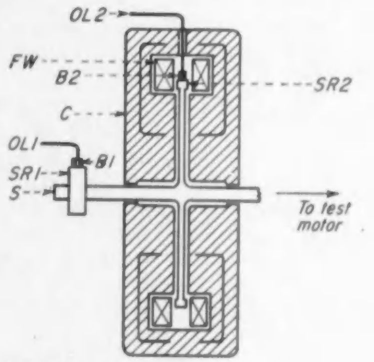
Speed-Torque Plot

From "A Speed-Torque Curve Tracer for Motors" by Alex Paalu, O. A. Smith Corp. AIEE Paper DP 56-512, presented at the Great Lakes District Meeting, Fort Wayne, Ind., April 16-18, 1956.

The author's methods for obtaining an instanteneous plot of speed-torque characteristics are essentially standard, but his equipment is not. He credits improvements in the latter with the more exact results he says he has obtained. He starts off his paper with a review of some of these other methods, and then goes into his own. His procedure depends on:

- obtaining a voltage proportional to the speed of the motor
- obtaining a voltage proportional to the torque developed by the motor
- plotting and displaying instantaneously a graph relating these two voltages.

In the equipment described by the author (patent pending) the speed voltage is obtained from a homopolar generator. The generator minimizes ripple, which could become troublesome, particularly at low motor speeds. The figure shows a cross-sectional view



OL1, OL2 — Output leads
FW — Field winding
B1, B2 — Contact brushes
SR1, SR2 — Slip rings on rotor and shaft
C — Steel core
S — Shaft coupled to test motor

of the homopolar generator construction.

A valid method for obtaining the torque voltage is to differentiate the speed voltage, since during the acceleration period the acceleration is very

nearly proportional to torque and is the time derivative of speed. The torque signal is applied to one pair of terminals of the cathode-ray oscilloscope that displays the desired characteristic curve. The other pair of terminals on the scope is fed from the output of an amplifier, which receives its input directly from the homopolar output. Thus the resulting trace on this scope axis is proportional to speed.

Piece-by-Piece Analysis

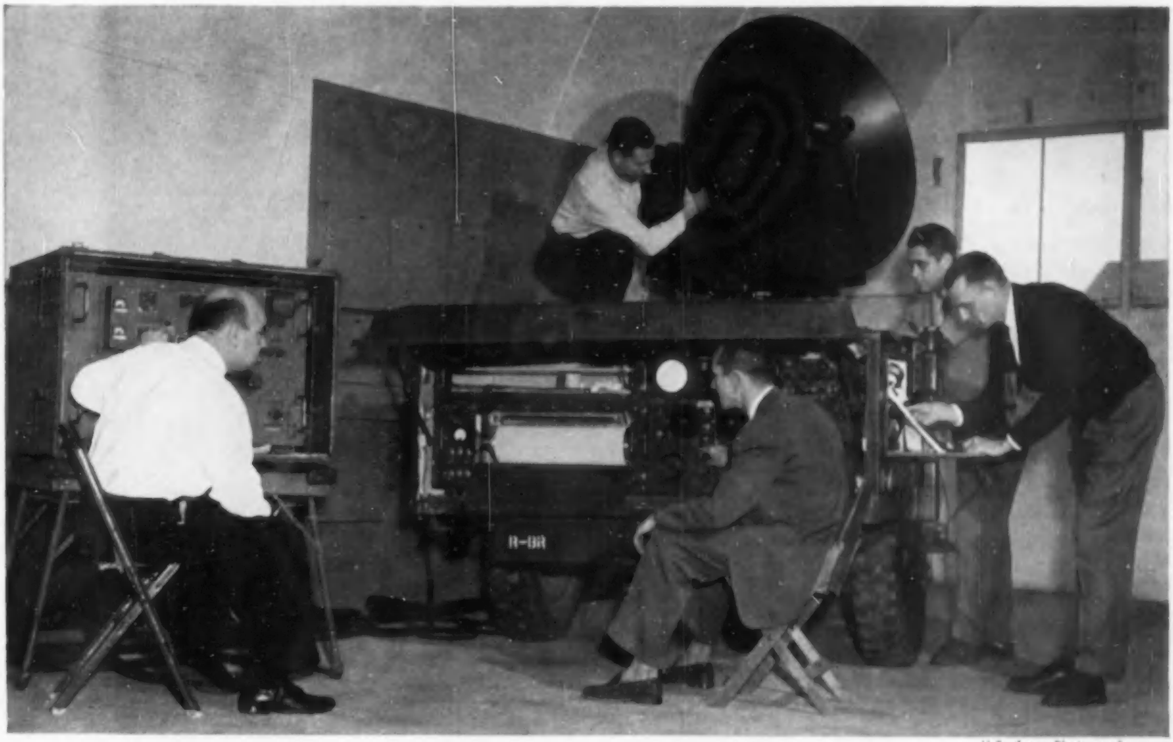
From "A Graphical Method for the Analysis of Piecewise Linear Control Systems, With Particular Application to Relay Controls" by R. H. Macmillan, Cambridge, England. ASME paper 56-SA-17, presented at the Semi-Annual Conference, Cleveland, June 17-21, 1956.

Macmillan presents a powerful graphical technique for the determination of the transient response of nonlinear control systems. In these systems he includes:

- relay controls
- relay system with constant output loading and dead time
- linear system with asymmetrical gain, dead band, and saturation
- linear system combined with relay action, and,
- approximation to component with variable gain

The initial step in the graphical technique is to find the characteristic curves of the system. "The approach used is to obtain the exact solution of the equations of motion over linear sections; the displacement and velocity . . . at the beginning of each section are then equated to those at the end of the preceding section. . . . One relates the velocity at the moment when the displacement is zero to the displacement when the velocity is next zero, i.e., the maximum subsequent displacement; the other characteristic curve relates the initial maximum displacement to the velocity when the displacement is next zero. Each curve thus relates a velocity to a displacement, as does a phase plane trajectory, but the two quantities do not occur simultaneously as in such a trajectory."

In any system under investigation the properties of its nonlinear and linear portions can be defined. By solving the equations of motion the maximum velocities and displacements, with time as a parameter, form the characteristic curves. From these curves one extracts the successive



U.S. Army Photograph

Electronic specialists at Ft. Monmouth SCEL Laboratories checking out radar and computing system designed for field use.

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This is one of a series of ads on the technical activities of the Department of Defense.

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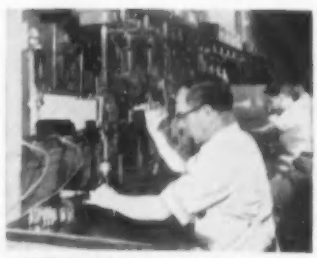


Skilled machinists at Ford Instrument Company, manufacturing precision parts for an Army military computer.

ABSTRACTS

maxima and minima points of velocity and displacement and plots them as a function of time. Thus these "salient points" sufficiently describe the transient responses of the system for practical purposes.

Some insight into the operation of the system can be gained simply by analyzing the relationship of the two characteristic curves. If the curves cross once, the point of intersection represents a sustained oscillation with an amplitude equal to the displacement at that point. "When the characteristics cross more than once, the intersections represent alternately stable and unstable states of sustained oscillation."

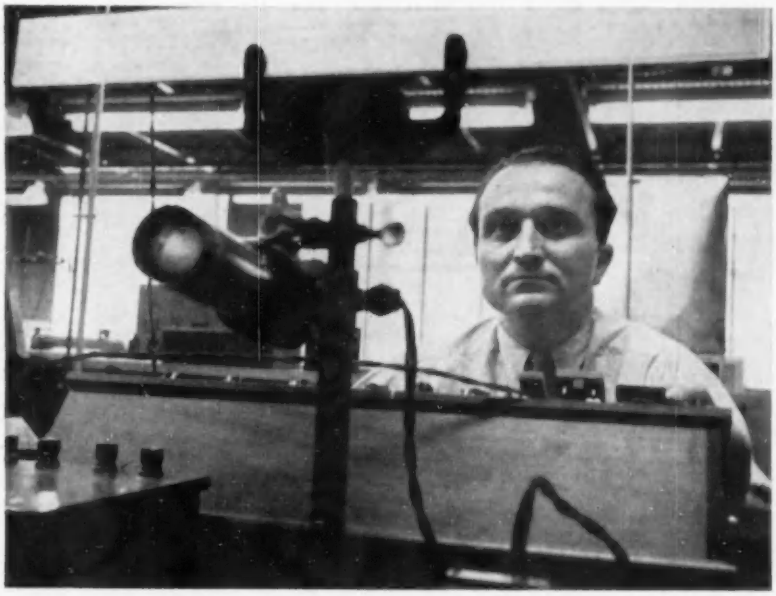
The author continues with applications in various relay-operated control systems. Starting with an ideal relay circuit, he then adds dead time in the switching operation of the relay. Alteration of the ideal relay characteristic curves proceeds on a straightforward graphical basis for this added involvement. In a similar graphical analysis the author evaluates the effects of backlash, dead zone, constant output loading, and solid friction.

Once a system has been analyzed by this relatively simple graphical technique it may be necessary to effect certain improvements in performance. Thus, the graphical equivalents of a "dead-zone break", "front-lash" and "variable-lead" added to the system show how and to what extent they improve operation of relay-controlled systems.

The usefulness of the article, in addition to introducing a new approach to the analysis of nonlinear systems, extends to many curves prepared by the author:

- Allowing for backlash, hysteresis, and dead zone
- constructing transients with proportional lead
- finding critical amplitude of disturbance to avoid overshoot with various amounts of lead and dead time

In an appendix to the paper, B. M. Brown, the Royal Naval College, shows the relation between the characteristic curves and the phase plane. When the displacement does not appear explicitly in the differential equations of motion "the characteristic curves are identical in shape and size with the phase plane trajectories." When the displacement appears explicitly, the characteristics require additional graphical construction, but they can be obtained.



Scientist at control box of a Sanford-Bennett High-H-Permeameter measures hysteresis loop of Indox ceramic magnet.

How temperature affects magnets

An interview with Dr. Rudolf K. Tenzer, scientist, The Indiana Steel Products Company

BECAUSE PERMANENT MAGNET remanence changes, resulting from varying temperatures, often necessitate corrections, compensations, or allowances, Dr. Tenzer undertook a series of studies on the subject. Some of the data used by him in answering the questions posed below resulted from work sponsored by the Wright Air Development Center of the U. S. Air Force. Reprints of an article by Dr. Tenzer on the subject are available by writing The Indiana Steel Products Co., Dept. P-7, Valparaiso, Ind.

Question: How does the remanence of permanent magnets vary with temperature?

Answer: Normally, remanence decreases with an increase in temperature . . . becoming zero at the Curie point, where all ferromagnetic properties vanish.

Question: Does a change in temperature result in a permanent change in remanence?

Answer: Not necessarily. Investigations which we have conducted show that temperature effects on ferromagnetic materials reveal both non-reversible and reversible variations.

Question: Can the result of these influences be evaluated?

Answer: Proper measuring techniques will evaluate the non-reversible variations as well as the reversible variations.

Question: Are non-reversible variations permanent changes in the remanence of a magnet?

Answer: Non-reversible variations are permanent until the initial remanence is restored by remagnetizing. This effect is not the same as irreversible metallurgical changes which prevent restoration of initial remanence by remagnetizing.

Question: What are reversible variations in remanence?

Answer: When a magnet has been stabilized for a certain temperature range, remanence variations within this temperature range are reversible.

Question: How are magnets stabilized for a given temperature range?

Answer: The magnet is exposed to repeated temperature cycling over a given range until the non-reversible variation becomes zero and remanence at room temperature remains the same for each additional cycle.

Question: Can the amount of remanence variation with temperature be predicted?

Answer: Our experiments in this field have produced quantitative results which can be used in predicting both the reversible and the non-reversible variations in remanence resulting from temperature change.

Question: Over what temperature range can these measurements be applied?

Answer: Our initial work in this field has been carried out in the temperature range from −60°C to 350°C.

Indiana expands research and production facilities

Currently under construction at Valparaiso, Ind., is a half-million dollar addition to the main plant of The Indiana Steel Products Co. The new structure will provide facilities for expanded research of magnetic materials, and increased production of Indox ceramic permanent magnets.

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NEW BOOKS

Inside the Computer

The Computer Handbook *(First Edition). 55 pp. Edited by Milton H. Aronson. The Instruments Publishing Co., Pittsburgh, Pa. $2.00.*

This handbook is of value to the control engineer who desires to learn —quickly and painlessly—how computers are constructed, how they function, and how he might make use of them in his own work.

It comprises six articles based on an integrated series of talks given at the first Computer Conference and Automation Exposition in New York City. These articles introduced electronic computers and data processors describing basic structure, general functioning, and typical uses of a number of the more commonly used, commercially available analog and digital special and general purpose computers now employed in industry, research, and business.

"Industrial Uses of Special Purpose Computers" covers the general role of these computers, both digital and analog. It illustrates their advantages by detailing three applications: control of a punch machine, control of a milling machine for contour milling of turbine blades, and recording instantaneous positions of a number of rotating shafts (the last by a special-purpose data processor).

"Analog Computers" outlines the structure and functioning of the major components of an analog computer (typified by the GEDA series), explains how to set up the computer for problem solution, and runs through determination of performance of a position servomechanism. This section also covers numerous technological and scientific areas where analog computers can be used, and comments on the advantages attending use of computers in practice.

"A Practical Approach to Analog Computers" treats construction, operation characteristics, and performance limitations of the major units of another analog computer (Electronic Associates' Model 16-31R), and the setups for solution of several different problems.

"Digital Computers—General-Purpose and DDA" covers construction and use of the two major types of digital computers. The general-purpose program-controlled numerical-calculation computer is typified by the Bendix Model G-15A. The digital differential analyzer, for solution

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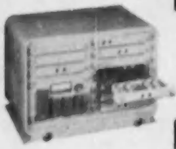

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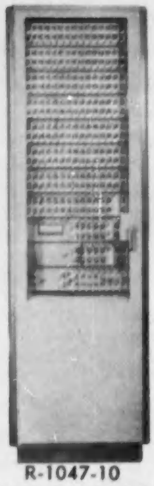

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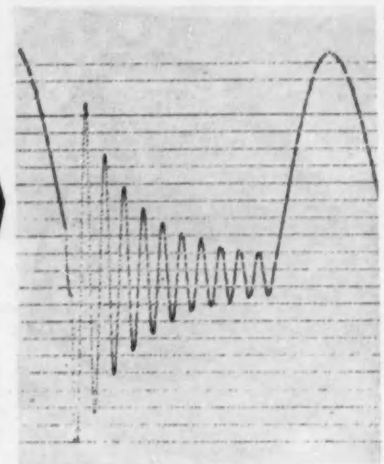

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of differential equations, is represented by the Bendix DDA. This section shows how typical problems are easily solved on these machines.

"Electronic Data-Processing Machines" illuminates the important role of punched-card machines in industry, commerce, finance, and science. The paper explains punching, verification, duplication, dual creation, tape reading, transceiving, interpreting, sorting, selecting, merging, matching, form feeding, summary punching, facsimile posting, and other basic operations. It breaks down a complete line of punched-card equipments (IBM), individually distinguished by relative overall capacity and speed of operation, showing how the pieces complement each other. Finally, the inherent unity of all data-processing machines is evidenced through an account of the five fundamental elements common to each.

"The Univac and Univac Scientific" discusses two large-scale computers that incorporate magnetic tapes as prime input components. Details of construction, operation, and typical uses of these Remington-Rand machines are given.

Modern Electric Drives

Moderne Probleme der Elektrischen Antriebe (*Modern Problems of Electric Drives*) *104 pp. Published by VDE-Verlag GMBH, Wuppertal-Berlin-Charlottenburg 5, Germany. 5 DM.*

This book contains seven papers selected from the conference on "Electrical Engineering in Industrial Plants" held Feb. 24-25, 1954, in Stuttgart under the auspices of the German Society of Electrical Engineers.

The papers, by outstanding specialists, cover various aspects of the application and control of modern electric drives. The authors and topics are: 1. W. Schneider, "Electrical Supply to Industrial Plants"; 2. R. Ulke, "The Technically and Economically Correct Choice of Electric Motors"; 3. F. Bunzel-Gecmen, "Development of Industrial Drive Technique"; 4. W.Backbart, "The Leonard Drive as a Modern Component of Machine Tools"; 5. R. Dehmlow, "Variable-Speed and Constant-Speed Electric Motor Drives"; 6. K. Kirsch, "Switching, Regulating and Protection of Electric Drives"; 7. W. Klickermann,

NEW BOOKS

"Photoelectric Switching Devices in Industry".

The writing is largely descriptive and its level suited to the application and design engineer. The concern is with problems of every-day practice and excellent line-drawings and cuts of modern industrial equipment illustrate the discussions. The volume should be of considerable interest to all control engineers who plan to keep abreast of modern advances in motor drives for industrial uses.

Symposium on F-R

FREQUENCY RESPONSE. *Edited by Rufus Oldenburger, director of research, Woodward Governor, Rockford, Ill. 372 pp. Published by The MacMillan Co., New York. $7.50.*

If a linear system is subjected to a sinusoidal input, the steady-state output (or response) of the system is also sinusoidal. The modulus and phase of this sinusoidal output, as produced by specified sinusoidal input over the range of frequency from zero to infinity, comprise the system's frequency response.

In recent years, design techniques based on frequency response have become a prime analytic tool in numerous branches of modern technology—especially in automatic control systems typified by servomechanisms, process control, and kindred areas of feedback systems. Because of widespread interest in this tool, the Dynamic Systems Committee of the Instruments & Regulators Div. of ASME sponsored a Frequency Response Symposium in New York City on Dec. 1 and 2, 1953. The present volume contains the papers presented at the symposium, plus seven other integrated papers selected by the editor.

The volume opens with an excellent five-page "Introduction", in which the editor outlines the chronological growth of frequency-response techniques in control. Dr. Oldenburger comments on the roles of many who contributed to this development. He notes the origins of these papers and summarizes the theme of each. He uses some of his own experiences in stressing the values of frequency-response techniques in practice, and closes with acknowledgments to some 50-odd persons who aided in preparation of this book.

A two-page table of contents shows that integration of the text is the re-


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sult of a thoughtful arrangement of articles. The 28 papers are grouped under nine broad headings, indicative of the central theme linking the individual items.

Part 1: Fundamentals entails six papers which are "directed to the beginner as well as to the expert". H. Nyquist explains how he came to write his famous (1932) paper, wherein he advanced the well-known Nyquist stability criterion. A. C. Hall remarks on the early rapid development and use of frequency-response theory under the stress of wartime necessities of improving fire control and radar tracking systems. R. H. Macmillan outlines the present state of some basic aspects of frequency-response theory, reviews current trends in research, and points out certain areas in need of cultivation. R. Oldenburger advances the recommendations of the ASME Dynamic Systems Committee for the presentation of frequency-response data, develops basic frequency-response theory for the benefit of beginners, and gives a survey of design criteria (supported by rigorous analysis) which will be of interest to the experienced designer.

A. M. Fuchs gives a classified bibliography of some 300 items on the history, theory, application, and associated aspects of frequency response. Many of these items carry summaries of their essential points of interest. A concluding paper by R. H. Macmillan—a detailed basic frequency-response analysis of regulating systems—is explained through the study of speed control of a gas turbine. Macmillan also discusses the role of control theory in modern engineering education.

Part 2: Frequency Response Aids includes two papers. One by K. Izawa, describes a sliderule (CtE, March '56, p. 115) and a nomograph which facilitates frequency-response computations. D. W. St. Clair and co-authors survey the construction and functioning of pneumatic, electric, and mechanical-hydraulic sine-wave generators for obtaining frequency-response data.

Part 3: Servo, Airplane, and Power System Applications contains H. A. Helm's detailed account of the design of a high-accuracy automatic contour-following lathe control system and A. C. Hall's detailed treatment of a system for hydraulic control (with electrical control components) by linearization and use of electric analogs of the hydraulic components.

NEW BOOKS

V. Oja's account of the frequency-response runs on the Swedish power systems in the course of a study of turbine speed control covers the resulting improvement in ac frequency regulation by matching the governor characteristics to those of the network and the disturbances. G. A. Smith and W. C. Triplett show the experimental procedures and computational techniques for determining frequency-response characteristics of aircraft from recorded transient flight characteristics.

Part 4: Process Control embodies articles by J. M. L. Janssen on the role of the deviation ratio in set-point control and by A. R. Aikman on application of frequency-response techniques in actual industrial situations—adjusting the controllers of a spray drier and of a heat exchanger. In addition, H. Kramers and G. Alberda discuss the distribution of residence times in continuous flow systems, and E. G. J. Eykman and C. J. D. M. Verhagen determine the transient behavior of cylindrical thermometers in fluid flows by a method of calculation that encompasses boundary-layer presence, a method that yields better results than the simple conventional R-C analog representation.

In *Part 5: Transient Response,* A. Leonhard shows procedures for efficient graphical calculation of transient response from frequency response by use of rectangular-segment approximation; W. R. Evans shows how to determine both transient and frequency responses from root-locus plots; S. Lees discusses methods for determining performance data, such as limits on absolute and relative stability, damping ratios, and undamped natural frequencies, by conjoining conformal mapping with Cauchy's integral theorum.

In *Part 6: Optimum Controls,* R. C. Oldenbourg and H. Sartorius consider the problem of minimizing linear-control area, quadratic-control area, and quadratic-mean output to periodic input of systems which return to equilibrium after disturbance. They investigate the relative advantages of design based on these criteria and show how to determine coefficients in a rational transfer function so as to minimize on a "practical-optimum" basis. J. H. Westcott advances two methods of synthesizing a linear compensating subsystem. In one the mean-square error of the entire system is minimized subject to certain subsidiary conditions in response to a statistically-de-

fined (stationary) input. The other is based on variational procedures. This work reveals that increase in the complexity of control beyond a certain measure may not appreciably aid performance.

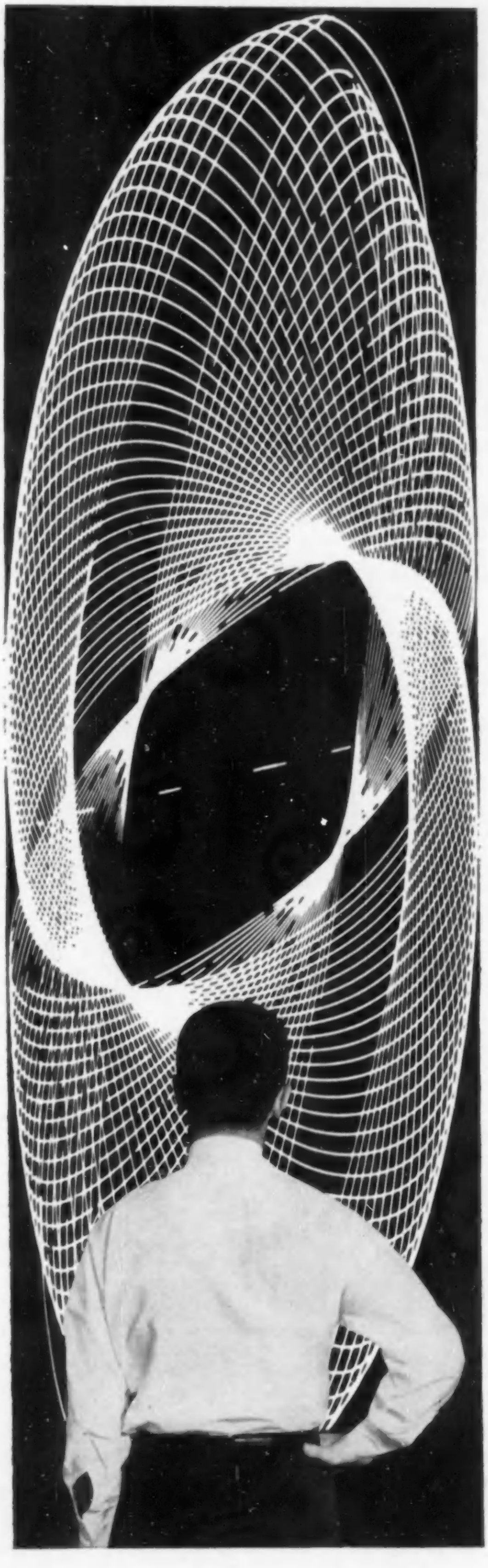
Part 7: Nonlinear Techniques embraces three excellent papers on the analysis of nonlinear systems by use of the describing function. L. C. Goldfarb (in a 1947 Russian paper) applies his analysis to continuous servomechanisms incorporating various types of nonlinearities. H. Chestnut, in his study of servomechanisms, incorporates dead-band and saturation effects. C. H. Thomas, in a study of stability in servomechanisms having dead-band effects, introduces such effects by example of gear trains with appreciable backlash. J. M. Loeb advances a functional treatment of nonlinearities wherein the amplitude and phase of generalized describing functions depend on the amplitude as well as the frequency of the input to the nonlinear element.

Part 8: Sampling Controls carries a translation of a lengthy Russian paper by Ya. Z. Tsypkin on the determination of the time response of sampled-data control systems. The method, a graphical calculation, yields knowledge of the real or imaginary part of the z-transform of the closed-loop response and subsequent utilization to determine performance aspects therewith. Particular interest attaches to a graphical means for determining whether a continuous or a sampled-date control may be best for a given system and to the fact that sampling-time is taken into account. R. H. Barker presents the z-transform procedure from an analytic point of view and applies it to a study of systems with time-delay in the feedback link.

Part 9: Statistical Methods is a single paper by M. J. Pelegrin. He details several studies made in France in connection with aircraft work. They encompass analysis stemming from Wiener's mean-square theory of optimum filtering based on stationary statistical inputs. Thus, both classical and statistical means are blended to enable optimum design of a variable-inertia regulator to control the speed of a load-varying electric motor.

In most instances the theoretical content of these papers is supported, illustrated, and enhanced by detailed numerical examples and figures.

Thomas J. Higgins
Professor of Electrical Engineering
University of Wisconsin



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Engineer...

you can achieve science-fact

far stranger than science-fiction

Today at AUTONETICS there are elaborate automatic control systems actually being developed, designed and *produced* in quantity that make the mechanics of the wildest space fantasies look ordinary.

For example, where in the pages of science-fiction is there a robot that compares with AUTONETICS' new airborne digital computer? This 3-cubic-foot brain can solve mathematical problems in one second that would take a math whiz with pencil and paper 9 hours, or require a clothes closet full of ordinary computer equipment. It can continuously integrate 93 quantities simultaneously . . . through 51 removable panels of etched, transistorized circuitry.

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CONTACT: Mr. R. C. Smith, AUTONETICS Engineering Personnel Office, Dept. 991-20 Con, P. O. Box AN, Bellflower, Calif.

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AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE

WHAT'S AHEAD: MEETINGS

JUNE

American Institute of Electrical Engineers, Summer and Pacific General Meetings, San Francisco — June 25-29

AUGUST

National Telemetering Conference, sponsored by Institute of Radio Engineers, American Institute of Electrical Engineers, Instrument Society of America, Institute of Aeronautical Sciences, Biltmore Hotel, Los Angeles — Aug. 20-21

Western Electronics Show and Convention (WESCON), Institute of Radio Engineers, Pan Pacific Auditorium and Ambassador Hotel, Los Angeles — Aug. 21-24

The Association for Computing Machinery, 11th Annual Meeting, University of California, Los Angeles Association address: Box 3251, Olympic Station, Beverly Hills, Calif. — Aug. 27-29

Sixteenth Annual Appalachian Gas Measurement Short Course, West Virginia University, Morgantown, W. Va. — Aug. 27-29

SEPTEMBER

Institute of Radio Engineers, Information Theory Symposium, Massachusetts Institute of Technology, Cambridge, Mass. — Sept. 10-12

American Society of Mechanical Engineers, fall meeting, Denver, Colo. — Sept. 17-20

Instrument Society of America, 11th Annual Instrument-Automation Conference and Exhibit, N. Y. Coliseum, N. Y. — Sept. 17-21

Industrial Electronics Conference (no exhibits), American Institute of Electrical Engineers, and Institute of Radio Engineers, Hotel Manger, Cleveland, Ohio — Sept. 24-25

OCTOBER

National Electronics Conference, Institute of Radio Engineers, American Institute of Electrical Engineers, Hotel Sherman, Chicago. — Oct. 1-3

EDITOR WANTED

CONTROL ENGINEERING's expanding editorial content requires that we add an assistant editor to the staff in the very near future. We are looking for a man, preferably in the age group 25 to 35, with:

A BS in ME, EE, Aero, or Physics, a minimum of two years' experience in designing and applying control systems, and some writing ability. The man will operate initially under the supervision of an Associate Editor, and will deal with manuscripts obtained in the field. Near future prospects: a senior technical editing post.

He must be willing to travel, and capable of organizing his thoughts rapidly and clearly on paper. The position open is in the New York editorial office of the magazine. The salary offered is on a level with existing engineering salaries for a well-qualified man. If interested, and available in the near future, please contact:

The Editor
CONTROL ENGINEERING
330 West 42nd Street
New York City, N. Y.

(Continued from preceding column)

American Institute of Electrical Engineers, Fall General Meeting, Hotel Morrison, Chicago — Oct. 1-5

Conference on Magnetism and Magnetic Materials, American Institute of Electrical Engineers, Institute of Radio Engineers, Hotel Statler, Boston. — Oct. 16-18

National Conference on Industrial Hydraulics, Annual Meeting, Hotel Sherman, Chicago. — Oct. 18-19

Institute of Radio Engineers, Third Annual East Coast Conference on Aeronautical and Navigational Electronics, Fifth Regiment Armory, Baltimore, Md. — Oct. 29-30

CONTROL PULSES

UNDERGROUND PLOT

Once condemned for beating its travelers into mute insignificance, New York City's vast subway network now gives every token-holder an opportunity to push a few buttons himself. Installed at the Times Square station is a computer-like machine (pre-programmed, of course), which at the touch of a finger prints out instructions for reaching any other station in the city. Near the buttons is a "display" that reveals the borough and the subway system involved, and the time it takes to get there. The "Directomat", designed by Max M. Tamir and built by Electrical Engineer Murray Schiffman, can be adjusted to print out 500 different instructions.

MAGNETIC BETTING TAPES

To some who have observed the ability of a computer to predict sports results, it was a natural step to the idea of using parts of the machine to store the bets. That's just what a trio of bookmakers in Los Angeles were doing when sheriff's deputies broke in on them last May. Their tape-recording of telephone bets assured complete accuracy of all figures —and easy erasure. But what could not be magnetically stored, unfortunately, was the $4,500 that the deputies found under a bathtub.

NO YAK, MORE JACK

A new cry has been taken up by British workers who see their lives changed by automation. Oddly enough, it is not the cry of those who fear replacement by automatic machines, but of those who know they'll remain when the machines take over. The cry is for "lonely pay" to compensate for loss of human companionship on the job. It was first raised at the Shell and Esso plants in Cheshire and became an issue at the annual conference of the British Amalgamated Engineering Union.

SPEEDER BEATS RADAR

Detroit police have sent back their speed-checking radar device for a few refinements. They brought what they thought was a "perfect case" before Traffic Judge John D. Watts, only to see it thrown out on grounds that their radar did not give the driver an even break: although it indicated that he had hit an illegal speed, it did not show that he had maintained this speed all the way across the radar screen. (Anyway, Michigan has no statute permitting admission of radar evidence in a speeding offense.)

- Research
- Testing
- Design
- Patents
- Instrumentation
- Control Systems
- Economic Studies
- Management

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When you are represented in the PROFESSIONAL SERVICES SECTION of CONTROL ENGINEERING, you are contacting the executives who are responsible for calling in the experts.

For further information on how to reach these executives, write:

Professional Services Section
Control Engineering
330 W. 42nd Street,
New York 36, N. Y.

CONTROL TRANSMITTER

(CLASSIFIED ADVERTISING)
SALES • BUSINESS
EQUIPMENT (Used or Resale)

"OPPORTUNITIES"

UNDISPLAYED RATE
(Not available for equipment advertising)
$1.80 per line, minimum 3 lines. To figure advance payment count 5 average words to a line.

DISPLAYED RATE
The advertising rate is $17.80 per inch for all advertising appearing on other than contract basis. Contract rates quoted on request.

PRIVATE CAPITAL AND/OR STOCK ISSUES ARRANGED

Interested in financing companies that are doing at least ½ million a year or more, running in the black, but could do a lot better with more capital. Amounts from $100,000 up available. Prefer companies in fields of electronics, engineering or research and development companies ready to go into production with backlog of orders. Will treat all inquiries confidentially.

BO-1888, Control Engineering
330 W. 42 St., New York 36, N. Y.

RELAYS

MINIATURE AIRCRAFT • TELEPHONE TYPE • HERMETICALLY SEALED • SENSITROLS • STEPPING SWITCHES • GUARDIAN • KURMAN • ALLIED • SIGMA • LEACH *and many others.*

LARGEST STOCK OF RELAYS IN THE WORLD
PRODUCTION QUANTITIES IN STOCK
Send for our latest bulletin C

324 CANAL ST., N.Y.C., 13, N.Y., WAlker 5-9642
Universal general corp.

MAY WE HAVE YOUR ATTENTION ?

The "CONTROL TRANSMITTER" serves as an active market place for buying and selling used and surplus elements and components of control systems. It will be consulted regularly by prospective buyers of such equipment offered by individual plants or dealers.

If you have used or surplus elements and components of control systems lying around idle in your plant, you can help other readers of the "CONTROL TRANSMITTER" who need such equipment by bringing it to their attention.

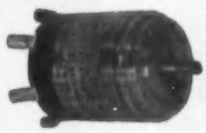
You may find bargains in hard-to-get components through the dealers advertising in this section. Make the reading of "CONTROL TRANSMITTER" a monthly habit.

SERVO SPECIALS

60 CYCLE SERVO MOTOR & GENERATOR

Navy Type CAN-211773 — 6.5 watts. Manuf. by Sangamo or Kollsman. Motor input is 115 volts per phase at 60 cycles. 2 pole construction gives speed of approx. 3350 rpm. Tachometer generator is of the constant frequency type with an output of 6.5 volts per 1000 rpm. Output shaft has a 10 tooth helical gear.
SB-513 **$37.50**

TYPE 15CX4A SYNCHRO TRANSMITTER

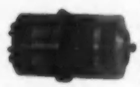


Designed for BuOrd to meet new specifications for smaller units. Voltage rating 115/90 volts at 400 cycles. Maximum electrical error 12 minutes.. Total weight 0.4 lbs. Dimensions 1.89" x 1.437" diameter. Synchro-type mounting.
SB-465 **$17.50**

TYPE AY101D PRECISION AUTOSYN TRANSMITTER OR CONTROL TRANSFORMER

26 volts, 400 cycle, single phase input. Will operate on 6 volts 60 cycles.
SB-24 **$9.50**

TYPE 1SF SYNCHRO



Manuf. by Bendix & Ford Instrument Co. Although this is a Navy Synchro designed for a 400 cycle excitation of 115 volts, it has been very successfully used on 60 cycle supplies not exceeding 32 volts. Since it has an internal mechanical inertia damper, it can be used either as a "transmitter" or as a "repeater". We strongly recommend this unit for many commercial applications requiring compact remote indicating assemblies.
SB-29 **$9.50**

Free—Write for 32 page complete catalog

We carry a complete line of Army-Navy-Commercial Synchros.

Servo-Tek
PRODUCTS CO.
INCORPORATED
1086 Goffle Rd. Hawthorne, N. J.
HAwthorne 7-3100 WUX, Hawthorne, N. J.

EMPLOYMENT OPPORTUNITIES

The Advertisements in this section include all employment opportunities—executive, management, technical, selling, office, skilled, manual, etc.

NATIONAL COVERAGE

Positions Vacant
Positions Wanted
Part Time Work

Civil Service Opportunities
Selling Opportunities Wanted
Selling Opportunities Offered

Employment Agencies
Employment Services
Labor Bureaus

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Subject to Agency Commission.

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$1.80 per line, minimum 3 lines. To figure advance payment count 5 average words as a line.

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Engineers and Scientists:

RCA...in New England

grows in

Aviation Electronics

RCA's aviation systems laboratory . . . at Waltham, in suburban Boston, broadens its research and development programs on electronic control systems for newest supersonic aircraft and missiles.

If you are interested in any of these programs, send a summary of education and experience to:

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Aviation Systems Laboratory
Radio Corporation of America
Dept. U-2-G
225 Crescent St., Waltham, Mass.

Control Systems
fire control, automatic flight, servomechanisms, system analysis & synthesis, instrumentation.

Target Sensing
radar, antennas, infrared, optics.

Digital Computers
systems & logic, pulse circuits, transistor circuitry, programming.

Mathematical Analysis
network theory, statistics.

Mechanical Design
heat transfer, shock & vibration.

RADIO CORPORATION OF AMERICA
DEFENSE ELECTRONIC PRODUCTS

• Foreign Service •

INSTRUMENT REPAIRMEN

Minimum 4 years journeyman experience testing, inspecting and repairing modern flow, pressure and temperature instrumentation in petroleum or chemical processing plant.

RELAY TECHNICIANS

Journeymen electricians. Minimum 2 years experience as a relay technician investigating and correcting line circuit troubles caused by relay failures. Unmarried man preferred.

Salaries $605 monthly plus generous living allowance; liberal, all-inclusive benefit program. Write giving full particulars regarding personal history and work experience.

Recruiting Supervisor, Box 163

ARABIAN AMERICAN
OIL COMPANY
505 PARK AVENUE
NEW YORK 22, NEW YORK

REPRESENTATIVES WANTED

Rapidly growing manufacturer of Failsafe Instrument Monitors has a few territories still open for energetic agents. Some of your lines should be electrical.

RW-1979, Control Engineering
520 No. Michigan Ave., Chicago 11, Ill

MECHANICAL RESEARCH ENGINEERS

Expanding industrial research programs have resulted in opportunities for engineers experienced or interested in any of the following fields:

Applied Mechanics
Fluid Mechanics
Reactor Engineering
Internal Combustion
Aerodynamics
Heat Transfer
New Product Design

These positions offer out-of-the-ordinary promotional opportunities in a stable, progressive organization which has enjoyed a threefold expansion in the last ten years. For technical application and literature describing our operations, write to

Technical Personnel Manager

BATTELLE INSTITUTE
505 KING AVENUE
COLUMBUS 1, OHIO

SALES ENGINEER

Are you interested in a sales engineering position in the field of instrumentation and automation? We are looking for engineering graduates, preferably Chemical or Electrical, 25 to 35 years of age for New York; Buffalo; Charleston, West Virginia; Philadelphia; Memphis, Detroit, Chicago, Tulsa, Los Angeles. Must be willing to relocate and travel adjacent territory.

Compensation on straight salary basis, all expenses paid and car furnished with liberal fringe benefits. Sales experience desirable, but not necessary as we provide Klein Sales Aptitude Test at our expense.

Successful applicants will receive thorough training course at our factory, Foxboro, Massachusetts, before being assigned to branch office.

If you are interested in a real opportunity with a progressive organization, please write:

J. J. Burnett,

THE FOXBORO COMPANY
4546 Oakton Street **Skokie, Illinois**

sending resume of education and past experience.

---

2 SYSTEMS ENGINEERS

This top rated company requires 2 systems engineers with 5 years experience in the electronic field. This Requires a knowledge of electrical circuits & experience in design for mass production. Starting salary $12,000. Company pays agency fee and relocation expense.

MONARCH PERSONNEL 28 E. Jackson Blvd.
CHICAGO 4, ILL.

SELLING OPPORTUNITY WANTED

Sales Engineering organization requires line of control instruments, computers, process pumps, throttling valves, pressure vessels, etc. Metropolitan NYC area coverage plus Long Island and New Jersey. Write: Autronic Associates Inc., 509 5th Ave., New York 17, N. Y.

transistor circuit engineers

Salary—
up to $12000
(Commensurate
with
experience)

Please send resume in confidence to:

Manager of Technical Personnel, Dept. 674

ARMA

Division
American Bosch
Arma Corp.
Roosevelt Field, Garden City, L. I., N. Y.

Challenging openings in the field of transistor circuit design and development . . . for application in fire control, navigation and guidance systems . . . utilizing analog and digital computing techniques.

SYSTEMS DEVELOPMENT, INC.

Requires one graduate electronic engineer with experience in circuit design, debugging in the Fields of Servo mechanisms and Pulse Techniques. Salary open—Stock Purchase Plan—Insurance Benefits. Send resume to:

JAMES HICKEN, President,
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Write for free copy of

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The engineers and technicians you want to reach are gathered in convenient, compact groups—as this 16-page booklet points out.

It keys the job titles these men hold to the McGraw-Hill publications they read for on-the-job information. It explains how you can make contact . . . channel, concentrate your employment advertising to just the men with the job qualifications you want.

Write for your free copy to

Classified Advertising Division
CONTROL ENGINEERING
330 W. 42nd St., N. Y. 36, N. Y.

DEVELOPMENT ENGINEERS

Honeywell's Aeronautical Division is one of several Honeywell Divisions specializing in automatic controls. At Aero the main specialties are guidance and automatic flight control of missiles and aircraft, airborne instrumentation, airborne servomechanism components and jet engine controls.

■ Top development positions are open for aeronautical, mechanical and electrical engineers. This means complete design and development responsibility for components and systems in the field of autopilots, fuel measurement systems, inertial guidance systems, vertical and rate gyros, stabilization platforms, and many others.

■ As a design engineer you will provide technical direction for draftsmen, technicians, model makers and evaluation engineers essential to the project. An engineering degree or its equivalent plus practical experience with related or similar equipment is required.

CONSIDER THESE ADVANTAGES

■ Minneapolis, the city of lakes and parks, offers you metropolitan living in a suburban atmosphere. No commuting.

■ Your travel and family moving expenses paid.

■ Salaries, insurance-pension programs, plant and technical facilities are all first-rate.

■ Honeywell, leader in control systems, manufacturers of over 10,000 different products, offers unusual diversification and variety. A sound growth company, continually expanding, it offers permanent opportunity to you.

WRITE TO US

If you are interested in a career at Honeywell, call collect or send your resume to Bruce Wood, Dept. CE-7-98, Aeronautical Division, 2600 Ridgway Road, Minneapolis 13.

MINNEAPOLIS
Honeywell
First in Controls

EMPLOYMENT OPPORTUNITIES

The Advertisements in this section include all employment opportunities—executive, management, technical, selling, office, skilled, manual, etc.

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Target Sensing
radar, antennas, infrared, optics.

Digital Computers
systems & logic, pulse circuits, transistor circuitry, programming.

Mathematical Analysis
network theory, statistics.

Mechanical Design
heat transfer, shock & vibration.

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Aerodynamics
Heat Transfer
New Product Design

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THE FOXBORO COMPANY
4546 Oakton Street **Skokie, Illinois**

sending resume of education and past experience.

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transistor circuit engineers

Salary—up to $12000 (Commensurate with experience)

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Division American Bosch Arma Corp.

Roosevelt Field, Garden City, L. I., N. Y.

Challenging openings in the field of transistor circuit design and development . . . for application in fire control, navigation and guidance systems . . . utilizing analog and digital computing techniques.

SYSTEMS DEVELOPMENT, INC.

Requires one graduate electronic engineer with experience in circuit design, debugging in the Fields of Servo mechanisms and Pulse Techniques. Salary open—Stock Purchase Plan—Insurance Benefits. Send resume to:

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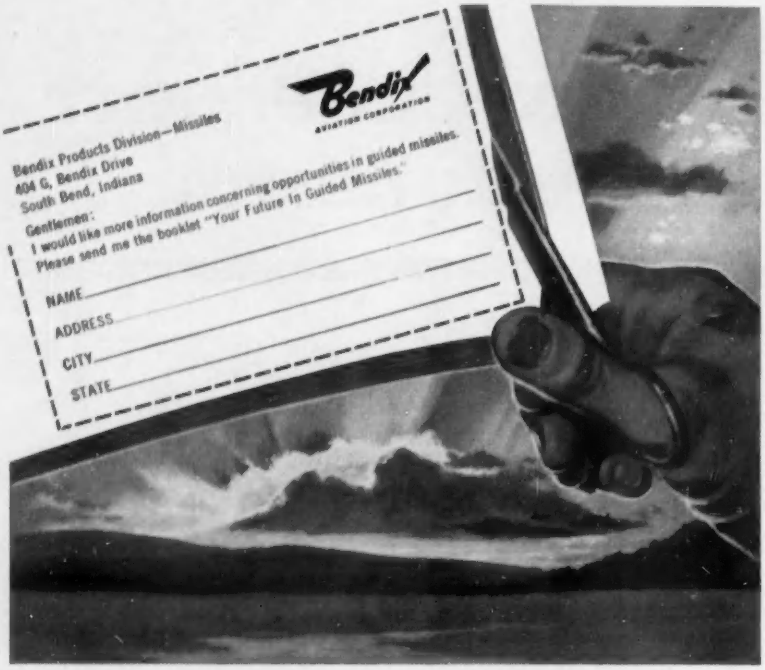
MINNEAPOLIS **Honeywell**

First in Controls

This coupon mailed TODAY



...may bring you a brighter TOMORROW!

There just isn't any question about it — the trained engineer of today has more opportunity than ever before.

However, and this is vitally important, the possibility for individual progress is far greater in certain organizations than in others. That's why every engineer concerned with his future should look into the job opportunities offered in the guided missile field.

Here at Bendix Products Division—Missiles, you can get in on the ground floor of a new, but proven, dynamic business with long-term potentials in the development, engineering and manufacturing of the nation's most important weapons system. It is truly the business of the future with many commercial as well as military applications.

Then, too, at Bendix Products Division—Missiles, you have all the advancement possibilities of a compact, hard-hitting organization backed by the resources of the entire nation-wide Bendix Aviation Corporation.

So that you may analyze for yourself the various job opportunities and the possibilities of rapid advancement, we have prepared a thirty-six-page book which gives detailed background of the functions of the various engineering groups.

Any ambitious engineer looks forward to a brighter tomorrow. May we suggest that the first step toward this goal is the mailing of the coupon for your copy of "Your Future in Guided Missiles".

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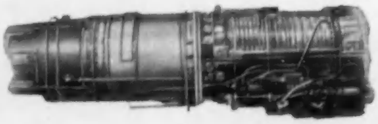

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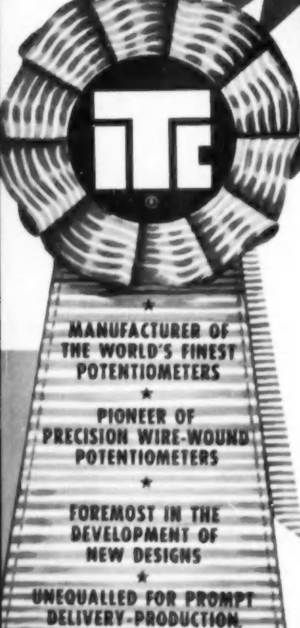

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